Westrail

Aluminium Rolling Stock

January 1976

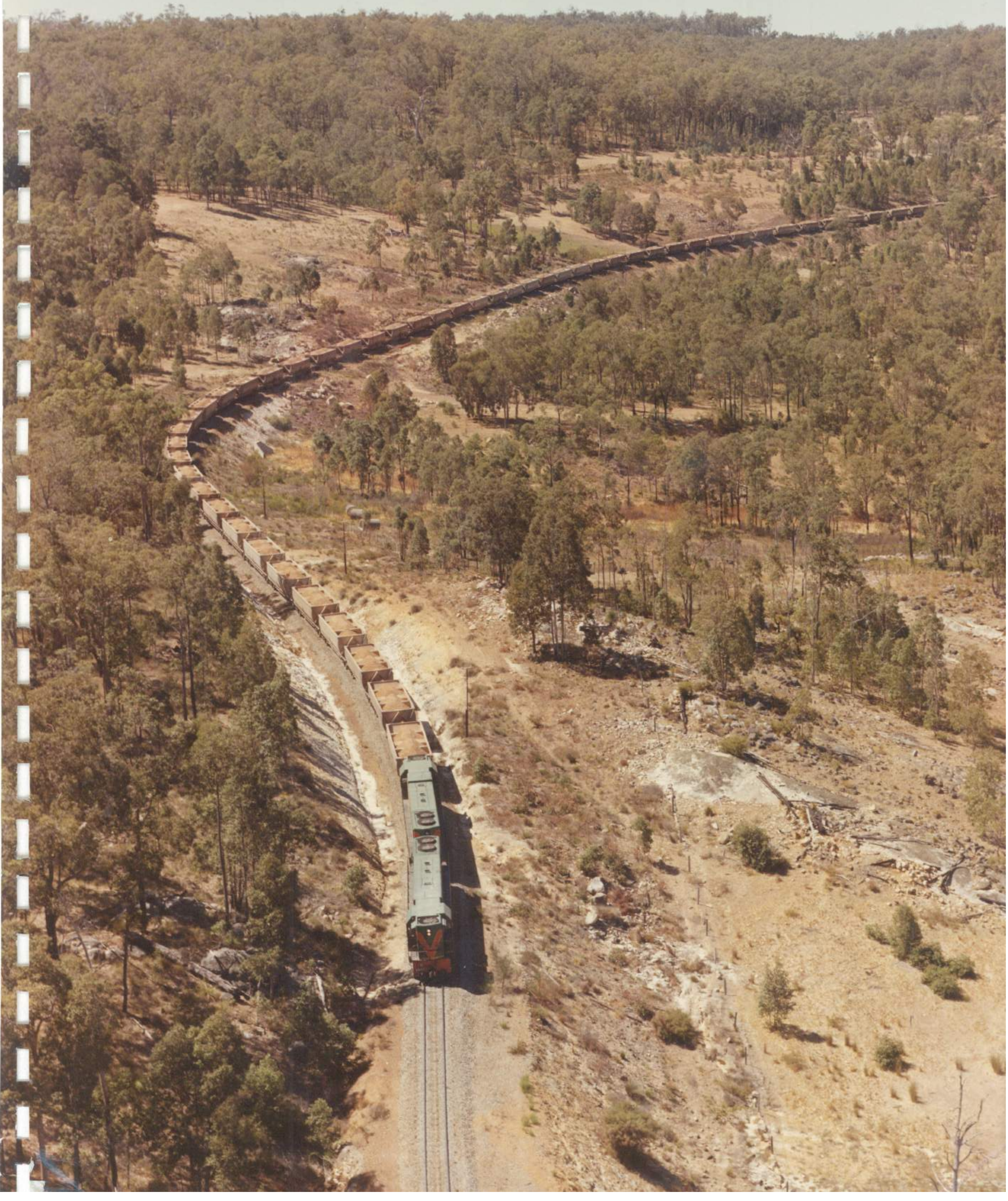

PHOTO PAGE

Captions are described on page 14

THE ALUMINIUM DEVELOPMENT COUNCIL

EXCELLENCE IN ALUMINIUM

Submission under

Category No. 1 PRODUCTS FOR INDUSTRY

Products which are currently manufactured for use in primary, secondary or tertiary industries, where that product represents the final or completed form or where it could be classified as a component or aid to manufacture.

Title: WESTRAIL ALUMINIUM ROLLING STOCK.

Entry No. 1/90

February, 1976.

Photo 1. Aluminium 'Class XC' Bauxite Wagon.
Tare 17.1 Tons. Load 62.9 Tons.

W E S T R A I L

ALUMINIUM ROLLING STOCK

Submitted by

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"He, who is theoretic as well as practical, is therefore doubly armed, able not only to prove the proprietry of his design, but also to carry it into execution."

Vitruvius.
1st Century B.C.

THE 'CLASS XC' ALUMINIUM WAGON

Photographs showing opposite ends.

Photo No. 2. Equipment End.

Photo No. 3. Handbrake End.

FOREWORD.

The lighter the tare, the greater the gain is axiomatic in the transport business.

Bulk transport of minerals, grains and other commodities in aluminium wagons has so increased revenue earning capacities that railways of the world are extending the use of this light-weight rugged material into body structures of freight cars and coaching stock with resultant increases in performance and economy.

Understood technically, aluminium in its many forms and with its inherent characteristics will prove an incalculable asset to designers for many years.

Photo No. 4. Loading at Jarrahdale.

Photo No. 5. Transporting Bauxite down the Darling Range

Photo No. 6. Unloading at Kwinana.

INTRODUCTION.

The continuous search by Railway Engineers to transport heavier loads in lighter vehicles and to design wagons for quicker turnround has never had such a boost in Australia as when the mineral boom hit Western Australia some fifteen years ago.

The challenge of transporting bulk commodities more efficiently in maximum pay-load vehicles of minimum tare weights in minimum turnround times has been eagerly accepted by Westrail, the largest transport business in Western Australia.

The use by Design Engineers of aluminium, in its various alloys, shapes, sections and characteristics to cover diverse transport exercises is clearly indicated in the body of this report.

Cases are also illustrated where aluminium wagons originally designed for the bulk transport of a given mineral have been, with comparatively minor modifications, converted to carry completely different commodities and heavier loads with economic advantages.

Yet other instances are shown where similar superstructures and their contents are conveyed on either Standard or Narrow Gauge railways, different bogies alone virtually accounting for this versatility.

A foremost builder of aluminium rolling stock, the Railway Workshops at Midland, Western Australia, in addition to designing and building light weight vehicles for Westrail requirements are continually being requested by private, mining and petroleum companies to manufacture aluminium vehicles for use in the railway systems of Australia.

Appendix 'A'   Section 15-2

Refers to the new corporate image Westrail launched by the Western Australian Government Railways on the 19th September, 1975.

Appendix 'B'   Section 15-3

Refers to the Westrail Workshops Exhibition at Midland Western Australia on the 12th November, 1975.

Photo No. 7. Aluminium Class JGE' Rail Tank Wagon.
Tare 18.2 tonnes. Load 45.8 tonnes.

INDEX TO SECTIONS

GENERAL INDEX

INDEX TO PHOTOGRAPHS

Cover - Westrail's Bauxite train, the 70 wagon consist, negotiating the 1 in 40 down grade in the Darling Range escarpment.

Photopage -

"Class XC" Bauxite Wagon	"Class JGE" Oil Tanker
Loading Bauxite at Jarrahdale	Unloading Bauxite at Kwinana
"Class XF" Alumina Wagon	Boom Welder
Salt Train. Lefroy to Esperance	Bandsaw cutting of Aluminium

INDEX TO FIGURES

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Photo No. 8. Aluminium 'Class XF' Alumina Wagon.
Tare 18.29 tonnes. Load 63.00 tonnes.

SECTION 1.

IMPERIAL AND METRIC UNITS.

Illustrations and calculations in this paper have been set out in either Imperial or Metric dimensions. The reason for this is, of course, the changeover to metrication.

Consignments by rail in Australia have been calculated in metric units interstate as from 1st July 1973, and the Working Time Table in Western Australia modified to operate intrastate as from 17th February 1974.

Prior to these dates imperial figures were used.

Future designs and drawings, including those previously designed in imperial units will be, of necessity, updated in hard metric units to suit the metric standards adopted by manufacturers of raw materials and hardware for railway rolling stock.

In the changeover process technical discrepancies are bound to occur and must be tolerated for the time being.

The previously designated Narrow Gauge of 3'-6" and Standard Gauge of 4'-8½" are now respectively re-designated as the 1067 mm and the 1435 mm Rail Gauges.

Maximum allowable gross weights of vehicles are restricted to the classification of the railroads over which they are to run. For example, the maximum allowable gross weight interstate (to comply with the A.N.Z.R. Code) is 75 tons and intrastate the maximum is 93 tons 15 cwt. In metric units the set limits are 76 tonnes and 96 tonnes respectively.

However, Westrail's system incorporates lighter gross restrictions in some areas yet to be upgraded.

Australia-wide, the whole metric conversion programme is running two years ahead of the timetable.

Decimal currency switching from pounds, shillings and pence to dollars and cents attained its tenth anniversary on the 14th February, 1976.

Conversion of weights and measures began five years ago on a ten year programme, but present indications are that it will finish in eight.

Quite a number of British and American firms producing railway equipment, however, are loathe to alter their own standards. Consequently imports from these countries are not all in metric units, the larger firms claiming that complete conversions of their products would prove prohibitive.

SECTION 2.

BENEFITS OF ALUMINIUM WAGONS

Generally, the benefits obtained by light-weight aluminium alloys compared with mild steel for railway rolling stock are :-

1. Much better payload to tare weight ratios.
2. Fewer wagons required for fixed tasks.
3. Ideal for bulk commodity or 'in-block' captive trains.
4. Less locomotive power energy required for the same number of wagons hauled.
5. Substantial increases in revenue earning capacities.
6. Improved loading and unloading facilities attendant with aluminium wagon design lessens labour charges and improves turnround times - in fact increases all round operating efficiency.
7. Greater elasticity - can deform three times that of steel without permanent deformation.
8. Less mechanical damage - therefore lowering of maintenance costs.
9. Incidence of 'hot boxes' reduced to a minimum.
10. Greater returns over the life of the wagon.
11. Less damage to cargoes carried.
12. Machine tool operations during manufacture generally quicker and easier reducing production man-hours.
13. Greater design flexibility and versatility.
14. Corrosion resistance reduces repair costs and minimises out-of-service times.
15. Greater resistance to weathering.
16. Non-contaminating - rendering special linings unnecessary.
17. Playing a steadily increasing part in railway development.
18. Complex extrusions available simplifying design, erection and promotes structural efficiency.
19. Easily adaptable to the 'cleanline concept' allowing freer egress of contents. Operating experience has proved that vibrators are not needed with correct aluminium design.
20. Residual cash value higher in comparison.

TABLE 1. ALUMINIUM WAGONS ON WESTRAIL

WESTRAIL built and owned — Appendix C.

CLASS	COMMODITY	DESCRIPTION	OUTLINE	GENERAL ARRANGEMENT	NOTE	REMARKS
						Narrow Gauge 3'-6"
XB	Bauxite	Yes	Yes	18352	a	Composite steel and aluminium
XC	Bauxite	Yes	Yes	20186	b	Aluminium superstructure
XBC	Bauxite	Yes	Yes	20358	c	Converted XB wagons
XR	Cement	Yes	Yes	20075	d	
XF	Alumina	Yes	Yes	22411	e)	Similar design - bottom
XFL	Lime	Yes	Yes	23639	f)	doors differ
JPA	Tanker	Yes	Yes	24127	g	Addendum refers
						Standard Gauge 4'-8.1/2"
WK	Cement	Yes	Yes	52703	h	
WWA	Grain	Yes	Yes	52235	j	

WESTRAIL built - Privately owned — Appendix D.

CLASS	COMMODITY	DESCRIPTION	OUTLINE	GENERAL ARRANGEMENT	NOTE	REMARKS
						Narrow Gauge
JGE	Tanker	Golden Fleece	Yes	24025	a	
						Standard Gauge
WJP	Tanker	Shell	Yes	54103)		
WJP	Tanker	Mobil	Yes	54103)	b	Addendum refers
WJP	Tanker	Ampol	Yes	54103)		
WJL	Tanker	Shell	Yes	53884	c	
WJK	Tanker	Esso	Yes	54165	d	

Built and owned privately — Appendix E.

CLASS	COMMODITY	DESCRIPTION	OUTLINE	GENERAL ARRANGEMENT	NOTE	REMARKS
						Narrow Gauge
JRB	Tanker	Mobil	Yes	21379	a	Tulloch built
XNG	Salt	Lefroy Salt Pty.	Yes	22464	b	Comeng built
XN	Coal	" " "	Yes	23659	c	Westrail conversion
						Standard Gauge
WL	Salt	Lefroy Salt Pty.	Yes	54595	d	Westrail conversion
WJD	Tanker	Mobil	Yes	21553	e	Tulloch built
WJE	Tanker	Mobil	Yes	21542	f	Tulloch built
WJF	Tanker	Mobil	Yes	52978	g	Tulloch built
WJG	Tanker	B.P.	Yes	52985	h	Tulloch built
WJH	Tanker	Caltex	Yes	52848	j	Comeng built
WJJ	Tanker	Ampol Caltex	Yes	52856	k	Comeng built
WJK	Tanker	B.P. Golden Fleece	Yes	52997	l	Tulloch built
WJM	Tanker	B.P. Shell	Yes	53004	m	Tulloch built
WJN	Tanker	Shell	Yes	21971	n	Tulloch built

ADDENDUM TO TABLE 1.

APPENDIX C.

(a) Originally aluminium body with steel doors and steel underframe.
(b) Aluminium wagons for transport of bauxite.
(c) "XB" to "XBC" conversion for in service compatibility.
(e) Aluminium wagons for transport of alumina.
(f) With exception of bottom door design, similar to (e).
(g) Narrow Gauge Tanker with tank identical to Standard Gauge "WJP".

APPENDIX D.

(b) Standard Gauge Tanker with tank identical to Narrow Gauge "JPA".
Nine (9) "WJP" Tankers are in service and six (6) currently under manufacture.

APPENDIX E.

(b) Original 3'-6" "Class XNG" Salt Wagon built by Comeng, Queensland.
(c) Converted to 3'-6" "Class XN" Coal Wagon by Westrail.
(d) Converted to 4'-8.1/2" "Class WL" Salt Wagon by Westrail.

Further reference to Table 1 reveals that aluminium vehicles running on Westrail are divided into three distinct categories :-

APPENDIX C. Westrail built and owned

Used for the bulk transport of Bauxite, Cement, Alumina, Lime, Grain and Petroleum products on both Narrow (3'-6") and Standard (4'-8.1/2") Gauge tracks, many wagons are manufactured in the Westrail Workshops, Midland, Western Australia.

Westrail's initial entry into the aluminium field was the "Class XB" bauxite carrier, a composite design of aluminium body on a steel underframe and steel doors, so designed that this system could obtain first-hand knowledge of this lightweight material under local conditions.

Subsequent designs consist of all-aluminium superstructures, i.e., above the bogies, except for proprietory lines of drawgear, brake equipment and hand brakes, thus attesting to the satisfactory trials.

APPENDIX D. Westrail built and privately owned

Rail Tankers in this category are totally designed and built in the Westrail Workshops at Midland, Western Australia, proprietory lines of "hardware" only being purchased. Westrail built vehicles include Standard Gauge vehicles for the Shell, Esso, Mobil and Ampol companies and Narrow Gauge wagons for Golden Fleece.

APPENDIX E. Built and owned privately

Sixty (60) aluminium vehicles are within this classification in Westrail and with one exception consist of Rail Tankers belonging to the Mobil, Shell, B.P., Caltex and Golden Fleece companies. The one exception is the original Narrow Gauge Salt Wagon "Class XNG" built by the Commonwealth Engineering Pty. Ltd. of Queensland for the Lefroy Salt Pty. Ltd., for the haulage of salt from Lake Lefroy to Esperance, a distance of 300 kilometres on the extreme Eastern leg of the W.A.G.R.

The use of aluminium with its high corrosive resistance has proved eminently suitable for this type of work.

Forty (40) such wagons were initially purchased for service on Narrow Gauge.

Twenty two (22) were subsequently converted to Standard Gauge "Class WL" with increased capacity for the owning company following the upgrading to Standard Gauge of the Kalgoorlie-Esperance section.

The remaining eighteen (18) were modified to Narrow Gauge "Class XN" for coal traffic (and grain when necessary) and are currently on hire to Westrail by agreement. Both modifications were carried out at the Westrail Workshops, Midland, Western Australia.

TABLE 2. NARROW GAUGE SALT WAGON CONVERSIONS

Wagon	Salt	Salt	Coal
Gauge	Narrow	Standard	Narrow
Drawing No.	22464	54595	23659
Class	XNG	WL	XN
Tare Weight	12.8 tons	15.75 tons	13.6 tonnes
Load Capacity	47.2 tons	59.25 tons	* 40.4 tonnes
Gross Weight	60.0 tons	75.00 tons	54.0 tonnes
Volume C ft.	1365	1769	1781
C.M.E. File	68/2509	UG 2213	74/2515

* For 54 tonne track, but has been increased on rails of higher classification, e.g., +10 tonnes on 64 tonne track.

The range covered by Aluminium Tankers may be gauged from an examination of the Narrow Gauge Tanker "Class JPA" (C.M.E. Drg. 24127) and the Standard Gauge Tanker "Class WJP" (C.M.E. Drg. 54103) in Section 17. Both tanks are dimensionally identical.

Despite this, however, aluminium wagon and tanker design to satisfy the requirements of Table 1, particularly Appendices "B" and "C" may be classified as a specialised science for private firms still insist on their own individual requisites and, to date, all attempts to design a Standard Tanker to suit all firms have proved abortive.

Cursory perusal of the included outlines will also reveal single, double and treble compartment tankers e.g., Classes "WJG", "WJJ" and "WJH" respectively.

COMPARATIVE TARE WEIGHTS

Mild Steel versus Aluminium Rollingstock

4.1 Various methods have been adopted to ascertain the saving in weight. Direct comparisons have been made when available e.g.,

Standard Gauge Grain Wagons

	Tare	Load	Gross
	T - C - Q	T - C - Q	T - C - Q
Class WW (steel)	24 13 0	69 2 0	93 15 0
Class WWA (aluminium)	19 2 1	74 12 3	93 15 0
Difference	5 10 3	5 10 3	Nil

Difference in Tare Load equivalent to extra Pay Load of 5.5375 Tons.

4.2 Wagons for which details are available are deducted from basic principles e.g.,

Narrow Gauge Bauxite Wagon

	Tare	Load	Gross
	T - C - Q	T - C - Q	T - C - Q
Class XC	17 2 0	62 18 0	80 0 0

Two bogies	8.795 tons)	
Draftgear	1.339 tons)	10.58 tons
Brakegear	0.406 tons)	

∴ Tare - Hardware weights = 6.52 tons aluminium.

4.3 Aluminium rail vehicles not necessarily carrying like commodities have been compared to steel tankers.

For Standard Gauge (SG) "Class WST" and for Narrow Gauge (NG) the modified "Class JTE" are the chosen datums.

TABLE 3. ALL-STEEL WAGONS - STANDARD GAUGE AND NARROW GAUGE DATUMS

Standard Gauge "Class WST" Steel fabrication					
Tare		Load		Gross	
T - C - Q	Tonnes	T - C - Q	Tonnes	T - C - Q	Tonnes
30 10 0		63 5 0			
30.5	30.9895	63.25	64.2652	93 15 0	95.2547
Narrow Gauge "Class JTE" Steel fabrication					
Tare		Load		Gross	
T - C - Q	Tonnes	T - C - Q	Tonnes	T - C - Q	Tonnes
24 8 1		29 11 3		54 0 0	
24.4125	24.8043	29.5875	30.0624	54.000	54.8667

To increase the capacity of the steel "Class JTE" six (6) Tons to a Gross Load of sixty (60) Tons by lengthening the barrel of 3/8" Plate at the centre of 7'-8" dia. ;

Material per foot -

$\pi \times 7.2/3 \times 1 \times 15$ lbs/ft. = 361 lbs. per ft. length

Contents per foot -

$\frac{\pi}{4} \times 7.2/3^2 \times 1 \times 62.1/2 \times 0.85$ SG = 2452 lbs. per ft. length

Material and contents = 2813 lbs. per ft. length

$\therefore$ Proportion of material : contents = 1 : 6.79 and for 6 Tons

Material $\frac{1}{7.79} \times 6$ = 0.7702 Tons)
) = 6 Tons
Contents $\frac{6.79}{7.79} \times 6$ = 5.2298 Tons)

Therefore, the weights for a modified steel "JTE" as the N.G. base :-

Tare		Load		Gross	
Tons	tonnes	Tons	tonnes	Tons	tonnes
24.4125		29.5875			
+0.7702		5.2298			
25.1827	25.5869	34.8173	35.3761	60.00	60.963

In an actual design, all stresses need to be checked.

For saving in weight of a similar aluminium design :-

Example : Modified steel "JTE" Tare 25.1827
Aluminium "Class JRB" Tare 14.8875

Saving of 10.2952 Tons

4.4 Standard Gauge Aluminium Tankers have been grouped together as saving from 8.1/2 to 9 Tons "across the board" when compared to mild steel counterparts.

TABLE 4. ALUMINIUM BUILT VEHICLES - SAVING IN TARE WEIGHTS

WAGON CLASS	GAUGE NG or SG	COMMODITY	DENSITY LBS/FT.^{3}	SAVING TONS	SAVING TONNES	COMPARISON
XB	NG	Bauxite	90	2.87	2.196	XB has original steel U/frame
XC	NG	Bauxite	90	6.52	6.6246	Basic principles
XBC	NG	Bauxite	90	1.87	1.900	Similar to XB modified
XR	NG	Cement	70	10.2327	10.3969	Against modified steel JTE
XF	NG	Alumina	65.4	6.52	6.6246	Similar design to XC
XFL	NG	Lime	60	6.52	6.6246	Similar design to XC
JPA	NG	Tanker	*	6.1876	6.2869	Against modified steel JTE
JGE	NG	Tanker	*	9.842	10.0000	Basic principles.
JRB	NG	Tanker	*	10.2952	10.4604	Against modified steel JTE
XNG	NG	Salt	66	5.893	5.9875	Basic principles.
XN	NG	Coal	50	6.538	6.6429	" "
WL	SG	Salt	66	6.12	6.2182	" "
WK	SG	Cement	70	7.7785	8.0140	Against steel WST
WWA	SG	Grain	50	5.5375	5.6263	Against WW steel version
WJD	SG	Tanker	*	Saving "across the board" 8½ to 9 tons		Against steel WST
inclusive	"	"	*			" " "
to	"	"	*			" " "
WJN	"	"	*			Against steel WST

NOTES: (i) * Indicates Sp.Gr. varies from 0.73 to 0.995.

(ii) Densities shown are FAQ (Fair Average Quality) and understandably vary from place to place and mine to mine.

(iii) Density Diagram 1 shows FAQ densities for 1975.

DIAGRAM 1.

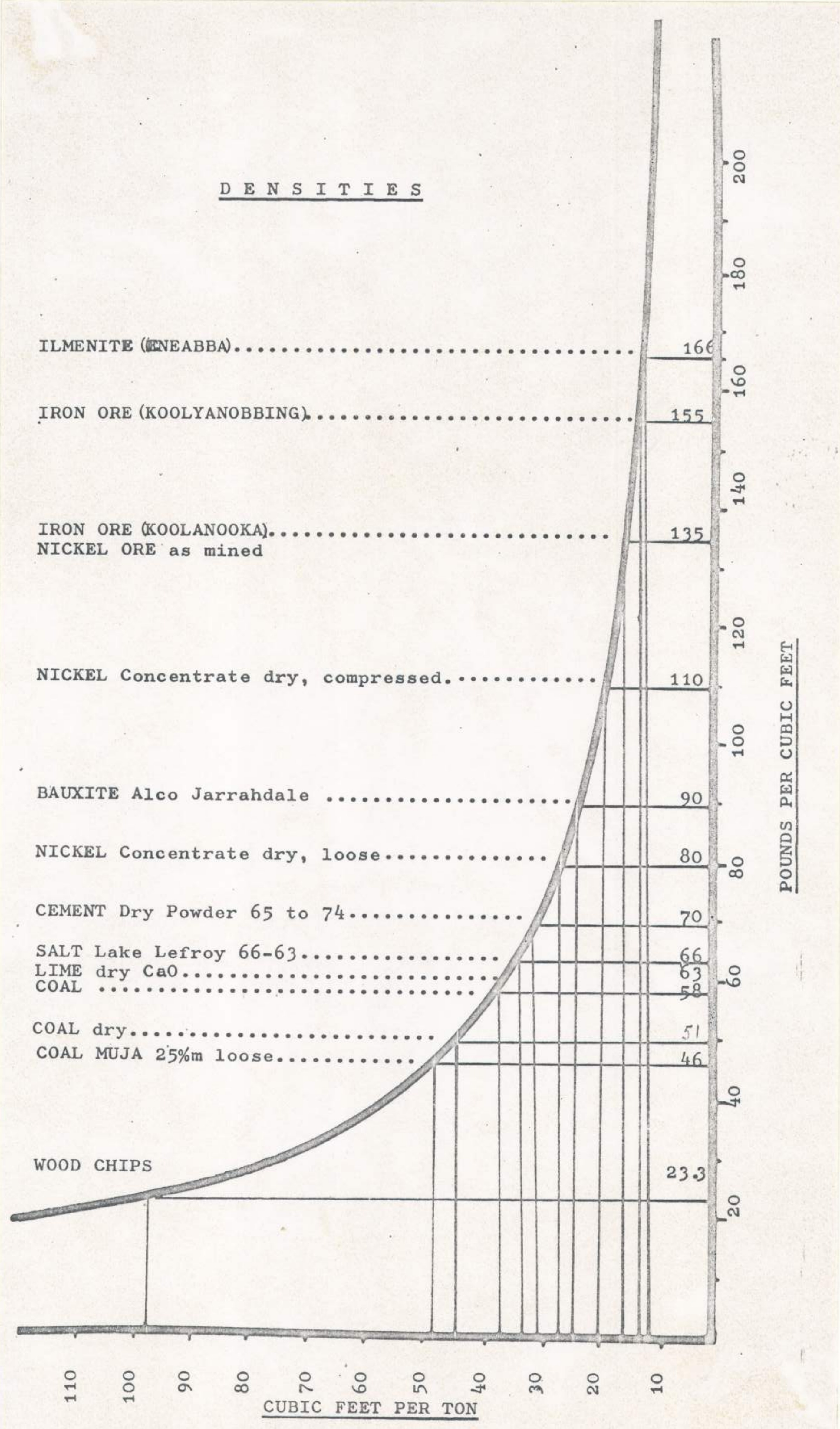


DIAGRAM 1.

BRIEF HISTORY OF ALUMINIUM WAGON DESIGN

The first application of aluminium alloy to wagon construction in this system was the original "Class XB" bauxite wagon which incorporated an aluminium alloy hopper, with steel doors, bolted to a steel underframe. Twenty four (24) were initially placed in service in 1963 and a further four (4) followed in 1967.

These wagons were later modified and re-classified "Class XBC" to operate jointly with the all-aluminium alloy "Class XC" bauxite wagons.

Technical details are as follows :-

PRINCIPLE DIMENSIONS	"CLASS XB"	"CLASS XC"
Length over coupling faces	44'-1"	44'-1"
Length over headstocks	41'-4"	41'-2"
Bogie centres	32'-6"	31'-9"
Maximum width	9'-6"	9'-6"
Overall height loaded	9'-9"	10'-3"
Volumetric capacity	1500 $ft.^3$	1690 $ft.^3$
Tare weight	20.75 Tons	17.10 Tons
Load	60.00 Tons	63.00 Tons
Bogies	Cast steel ride control type fitted with clasp brakes and C.I. blocks. Package type roller bearings for maximum availability.	Cast steel ride control frame with Auscopac brake units fitted with brake cylinders integrally mounted in bogie brake beams and high friction composite brake blocks. Package type roller bearings.
Material of construction	Underframe - steel Plate to ASS A33-1955 Cl.E Rolled sections to AS B14-1940 Hopper Aluminium Alloy Plate to Alloy AA 5083-H11A Extrusions to Alloy AA 6061-T6	Aluminium Alloy Plate to Alloy AA 5083-H321. Extrusions to Alloy AA 6061-T6

Currently, there are twenty six (26) different designs to suit specific requirements engaged on the W.A.G.R., no less than half having been fully designed, drawn in detail and built by Westrail.

Pertinent references have been made to these vehicles, but to submit full details of all designs would cloud the purpose of this submission.

Consequently, the first Westrail produced all-aluminium superstructured wagon, the "Class XC", used for the transport of bauxite from Jarrahdale in the Darling Range to the unloading site at the Kwinana industrial complex, a distance of forty six (46) kilometres, has been selected as the spearhead design described in detail in Section 7, following the experience gained from intensive research described in Section 6. The first twenty two (22) were built in 1968; eighty four (84) now cover this service.

PRELIMINARY REQUIREMENTS

Currently known as "Alcoa of Australia Ltd." the mining company originally required for their operation a suitable wagon for receiving bauxite, crushed to pass a one inch screen, from overhead storage bins at the mine site, loading at the rate of 1500 tons/hour and capable of discharging the lading into under-rail hoppers at the refinery at the rate of 1400 tons/hour.

Alternative tonnages estimated by Alcoa to be hauled commencing 1963 (and on which wagon requirements and freight costing were calculated) were for 300 000, 600 000 and 1 000 000 tons/annum, which were far exceeded in later years.

Capital investment involving the fleet of bauxite wagons represents some $3m. (Aust.)

The growth of aluminium production in Western Australia is detailed in Section 11.

PRE-DESIGN RESEARCH, TESTS AND DEVELOPMENT

CAUTIOUS APPROACH

Despite the many benefits of aluminium (listed in Section 2), its application to railway rolling stock was viewed with caution by Westrail's designers; in fact, the first application incorporated an aluminium alloy hopper bolted to a steel underframe, as previously described in Section 3.

Since then, after experimentation, development and technical research, aluminium in the rail vehicle field has gained impetus, now being readily accepted by designers, fabricators and users. Pioneering work included the manufacture of scale and full-size models, and means to positively assess the varying intensities of internal, fatigue and welding stresses.

Quicker manufacturing methods, use of extruded sections and advanced techniques with aluminium alloys clearly demonstrate the adaptability of this metal to the trying railroad conditions.

OPTIMUM MAXIMUM GROSS WAGON WEIGHT

A feasibility study, based on predicted tonnages, was carried out to evaluate the use of bogie wagons as follows :-

(a) Conversion and use of existing rolling stock. (54 ton gross)

or (b) Construction of new rolling stock to a maximum axle loading on rail of 15 ton (60 ton gross)

or (c) Construction of new rolling stock to an optimum maximum axle loading on rail limit of 20 ton (80 ton gross).

Results of this study eliminated (a) because of the unsuitability of any existing wagon for conversion, both practically and economically, leaving (b) and (c) the alternatives.

A comparison of the estimated load/tare ratios between a 60 ton gross on rail wagon and an 80 ton gross on rail wagon of similar construction, favoured the 80 ton wagon because body, drawgear, brake gear and bogie weights do not increase in direct proportion to the increase in gross wagon weight.

The determination of 80 ton as the optimum maximum gross on rail was arrived at by

(a) The maximum axle loading due to rail bending moment limitations, which for 82 lb/yard rail with adequate ballast depth and sleeper spacing is 20 ton/axle.

and (b) A maximum wheel load limit per unit of wheel diameter, or, more commonly termed the P/D ratio. Proposed American practice, in 1961, for economical rail life was 800 lb/inch for 33 inch diameter wheels. (*) Using our standard 31½" new wheel diameter and allowing for 1.3/4" tread wear to condemning, at 800 lb/inch of wheel diameter, the wheel load was limited to 10 ton or 20 ton/axle.

A check inspection of wheels operating in service, under a 15 ton axle load, revealed evidence of excessive rail-wheel contact stresses occurring on the outer edges of the wheel tread, causing the metal of the tread to flow outwards. This condition was attributed to worn wheel flanges allowing the wheel to contact the rail as shown in Fig. 1. Because of this finding, the wheel width for the 20 ton axle load was increased from the standard width of 4½" to 5" to provide full wheel to rail contact under adverse flange wear conditions. To date no cases of outer wheel tread failure, as outlined above have been found on the 5" wide wheels under these wagons.

* Reference : American Railway Engineering Association Bulletin, Volume 62 No 565 P955-968, The effect of heavy wheel loads on rail as observed on the Quebec, North Shore and Labrador Railway by G.M. Magee. Director of Engineering Research A.A.R.

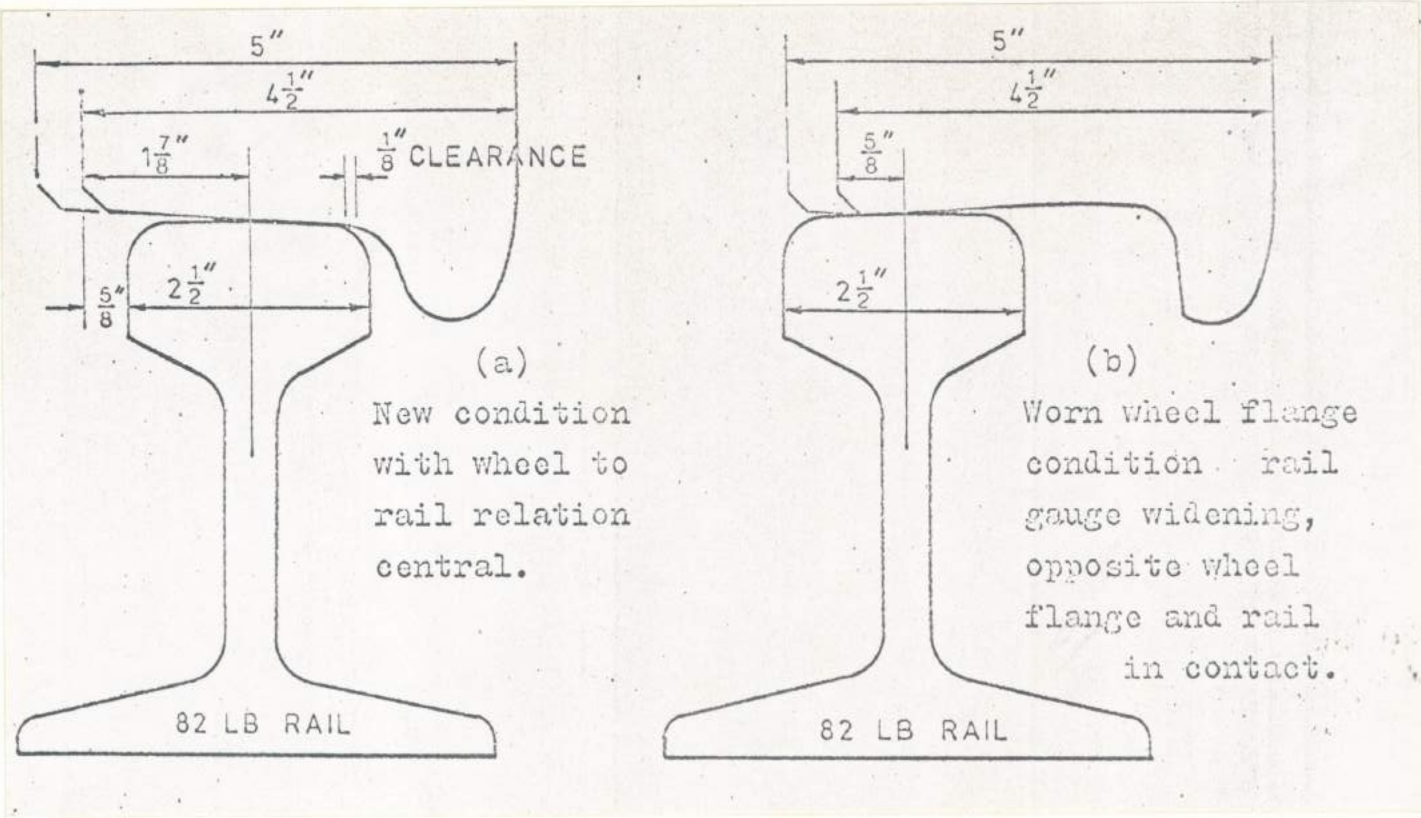


Fig. 1. Wheel to rail contact under new and worn conditions.

P/D ratio for XC wagon of 20 ton/axle on rail.

P = load in tons/axle at rail.
D = diameter in feet. (31½" new and 28" condemned)

$$P/D = \frac{20}{1} \times \frac{12}{31.5} = 7.62 \text{ for new wheels}$$

$$P/D = \frac{20}{1} \times \frac{12}{28} = 8.57 \text{ when wheels are condemned.}$$

P/D ratios adopted in other countries. (*) are as shown in table 5. below.

TABLE 5. P/D RATIOS

RAILWAY AUTHORITY	PERMISSIBLE RECOMMENDED P/D RATIO	MINIMUM WHEEL DIA. TO CONFORM	REMARKS
A.A.R.	up to 9.16	26.2"	
German	7.6	31.58"	850 mm dia. for 21.6 tonnes axle load at 75 km.p.h. speed.
Japanese	4.5 to 6 8	40" 30"	For 3'-6" gauge New Tokaido lines.
UIC/ORE	Not stated	20.2"	Based on UIC/ORE formula and U.T.S. of 55 T.S.I. for rail.
British	up to 7	34.3"	Speed not to exceed 55 m.p.h.

* Reference: Rail-Wheel Contact Stresses, by N. Rajamani and K.R. Subramaniam, Indian Railway Technical Bulletin, May 1968. P54 - 58.

RAILWAY PRACTICES.

Extensive research and investigation into the types of hopper and bottom discharge rail wagons utilised on haulage of bauxite throughout the world was carried out, but not any satisfactory design could be found to suit Alcoa's requirements. Wagons used elsewhere were conventional hopper wagons with three or four small bottom discharge openings and 30^{o} angle slope sheets, both features requiring the use of a car shaker to completely discharge the bauxite.

As a completely self-discharging wagon was evidently the most economical method to meet the unloading tonnage rates, the decision was made to develop and design a special purpose wagon specifically for haulage of bauxite.

Conflicting reports on density and angles of slope sheets required to self discharge bauxite, necessitated the undertaking of preliminary experimental work on a sample quantity of the bauxite to be hauled to ensure that wagon outlines evolved were compatible with the lading.

Results of this experimental work established the following design criteria :-

(a) Varying of the moisture content, altered the flow characteristics. The critical moisture content was found to be between 8 to 9%, when the bauxite proved most tenacious and difficult to discharge. Hence (b), (c) and (d) below were determined using bauxite within this moisture content range.

(b) Slope sheets need to have a minimum angle to the horizontal of 50^{o}.

(c) Valley angles of less than 55^{o} caused the bauxite to hang up.

(d) A discharge opening as large as possible was required to overcome arching or bridging of the bauxite.

In addition to the above, railway practice at the time limited the maximum centre of gravity of the loaded wagon to 5'-8" above rail level.

ESTIMATES OF WEIGHTS AND COSTS.

Estimates of the approximate tare weights, using similar type wagons in service in other countries as a guide, and costs for an 80 ton gross wagon on conventional design and construction in mild steel, high yield stress structural steel and aluminium alloy were prepared. The estimated loads, tares and costs of each are shown in Table 6.

TABLE 6. LOAD TARE COST COMPARISONS.

MATERIAL OF CONSTRUCTION	MILD STEEL	HIGH YIELD STRESS STRUCTURAL STEEL	ALUMINIUM ALLOY
Load/tare ratio	2.33:1	2.63:1	3:1
Payload	56 ton	58 ton	60.0 ton
Tare	24 ton	22 ton	20.0 ton
Material price/ton	$100	$180	$1 200
Cost per wagon	$14 400	$15 600	$21 000

NOTE: The estimated tare for aluminium alloy was later proven to be too high. The final XC wagons weighed in at 17.1 tons.

Using the load capacities and tares in Table 6, the numbers of wagons and trips required, neglecting limits of existing locomotive hauling capacity, are tabulated in Table 7.

TABLE 7. WAGON NUMBERS AND TRIPS

Ton per annum	Ton per day	No. of wagons, gross loads and tares based on load/tare ratios of											
		2.33:1 Mild Steel				2.63:1 High Yield				3:1 Aluminium			
		No. wagons reqd.	Gross load cap. ton	Gross tare ton	No. of trips daily	No. wagons reqd.	Gross load cap. ton	Gross tare ton	No. of trips daily	No. wagons reqd.	Gross load cap. ton	Gross tare ton	No. of trips
300 000	1 200	22	1 232	528	1	21	1 218	462	1	20	1 200	400	1
600 000	2 400	22	1 232	528	2	21	1 218	462	2	20	1 200	400	2
1 000 000	4 000	24	1 344	576	3	23	1 334	506	3	23	1 380	460	3

The estimated wagon costs and total capital expenditure for wagon numbers to haul up to 600 000 ton/annum from Tables 6 and 7 are shown in Table 8.

TABLE 8. WAGONS AND COSTS

WAGON LOAD/TARE	COST PER WAGON	NO. OF WAGONS INCLUDING 3 SPARES	TOTAL COST
2.33:1	$14 400	25	$360 000
2.63:1	$15 600	24	$374 400
3:1	$21 000	23	$483 000

Since Alcoa, in 1962, doubted that tonnages would ever reach the 600 000 ton/annum level, the additional cost to build all aluminium wagons could not be justified. The mild steel wagon construction was rejected on account of the trailing load of an empty train consist exceeding the existing single locomotive maximum hauling limit of 480 ton on the 5 miles of 1 in 40 grade, thus requiring either the running of additional trips with reduced wagon numbers or double heading which would be a waste of locomotive power. A high yield stress structural steel wagon consist would just satisfy this requirement.

However to appease the clients, Alcoa, who were urging for a wagon design in aluminium alloy to be used on the haulage of their bauxite, and the Railways to gain design and constructional experience in the use of aluminium, agreement was reached that the wagon would be of composite construction using a combination of a high yield stress structural steel underframe and doors with an aluminium alloy hopper. This action placed the Western Australian Government Railways to the forefront, in Australia, of the trend toward the use of aluminium alloy in hopper bogie wagon construction. The only other application at the time, of aluminium alloy in hopper type wagon construction in Australia, was in Queensland, where a "VJM Class" four wheeled wagon fitted with a hopper body fabricated from aluminium alloy, mounted on a steel underframe, was undergoing life expectancy tests in coal traffic.

Preliminary wagon outlines of alternative conventional designs, were prepared and submitted to Alcoa for their consideration and approval of the wagon concept most suited to their planned loading and unloading facilities. Ultimately the "XB" outline with curved hopper sides was first introduced into the Western Australian Government Railways with an aluminium content.

BASIC WORKING STRESSES OF ALTERNATIVE METAL CONSTRUCTIONS

Mild Steel Construction

Allowable design stress limits for construction in mild steel to ASS A33 for plate and ASS B14 for rolled steel sections, as laid down by The Australian and New Zealand Railways Code of Practice, (*1)were :-

Combined stresses in centre sills and structural members	20 000 lbf/in^2
Combined stresses in bolsters and cross bearers	15 000 lbf/in^2
Maximum direct stress	16 000 lbf/in^2

High Yield Stress Structural Steel Construction

The allowable design stresses for construction in high yield stress structural steel to BS 968 were, in the absence of a specific Code for railway applications, determined by applying the same factor of safety as used for mild steel construction in direct proportion to their respective yield points, provided these stresses did not exceed the yield point of the high yield stress structural steel divided by 1.8 (*2) The allowable design stress limits so derived were :-

Combined stresses in centre sills and structural members	27 000 lbf/in^2
Combined stresses in bolsters and cross bearers	22 500 lbf/in^2
Maximum direct stress	24 000 lbf/in^2

Aluminium Alloy Construction

In the absence of any specific code covering the application of aluminium alloys in railway rolling stock, the allowable stress for simple elastic analysis of static structures for tension and bending were derived by using a safety factor of either 2 on the guaranteed yield strength, or of 3 on the guaranteed ultimate strength (provided that this results in a factor of at least 1.67 on the yield strength), whichever gives the higher stress. The safety factors and the two aluminium alloys selected follow practice proven to be satisfactory from exhaustive tests on all aluminium alloy self supporting wagons constructed and tested in Canada. (*3)

Allowable basic design stresses for the two aluminium alloys used (*4), using 5356 filler alloy for all welds, were :-

Plate to alloy 5083 - H11A & H321

(see Diagram 2 for buckling diagrams)

Temper H11A was used on the Class XB wagons only. Temper H321 has been used in subsequent designs.

Basic design stresses (static)

	H11A Temper	H 321 Temper
Unwelded or welded longitudinally (see Note 1)	13 300 lbf/in^2	15 500 lbf/in^2
Transversely welded	10 800 lbf/in^2	10 800 lbf/in^2

Reference: *1 The Australian and New Zealand Railway Code of Practice, Section C.

*2 Design Manual for High Strength Steels, by H. Malcolm Priest, United States Steel Corporation. P13 - 14.

*3 Design and Testing of a Self-Supporting Aluminium Covered Hopper Car, by R.A. Campbell and I.H. Jenks, American Society of Mechanical Engineers Paper number 61 - WA - 236.

*4 Strength of Aluminium, by Aluminium Company of Canada Ltd., First, Second & Third Editions.

Extrusions to alloy 6061 - T6

(see Diagram 3 for buckling diagrams)

Basic design stress (static)

	H 321 Temper
Unwelded or welded longitudinally (see Note 2)	17 500 lbf/in^2
Transversely welded	8 000 lbf/in^2

For each alloy, the allowable shear strength was taken as 0.6 the corresponding allowable tensile strength, and the allowable bearing stress as 1.6 times the corresponding allowable tensile strength.

Note 1 Longitudinal welds have little effect on the overall static strengths of members provided that the area of weld and heat affected zone is small compared with the area of the member.

Note 2 The above stresses apply for static structures. Structures subject to dynamic loads, such as railway rolling stock, are to have the accelerating forces, expressed as a fraction of the dead weight, super-imposed on the static load, the resultant loads to be then treated as static loads for calculation of stresses. Dynamic structures should also be examined for possible fatigue failure.

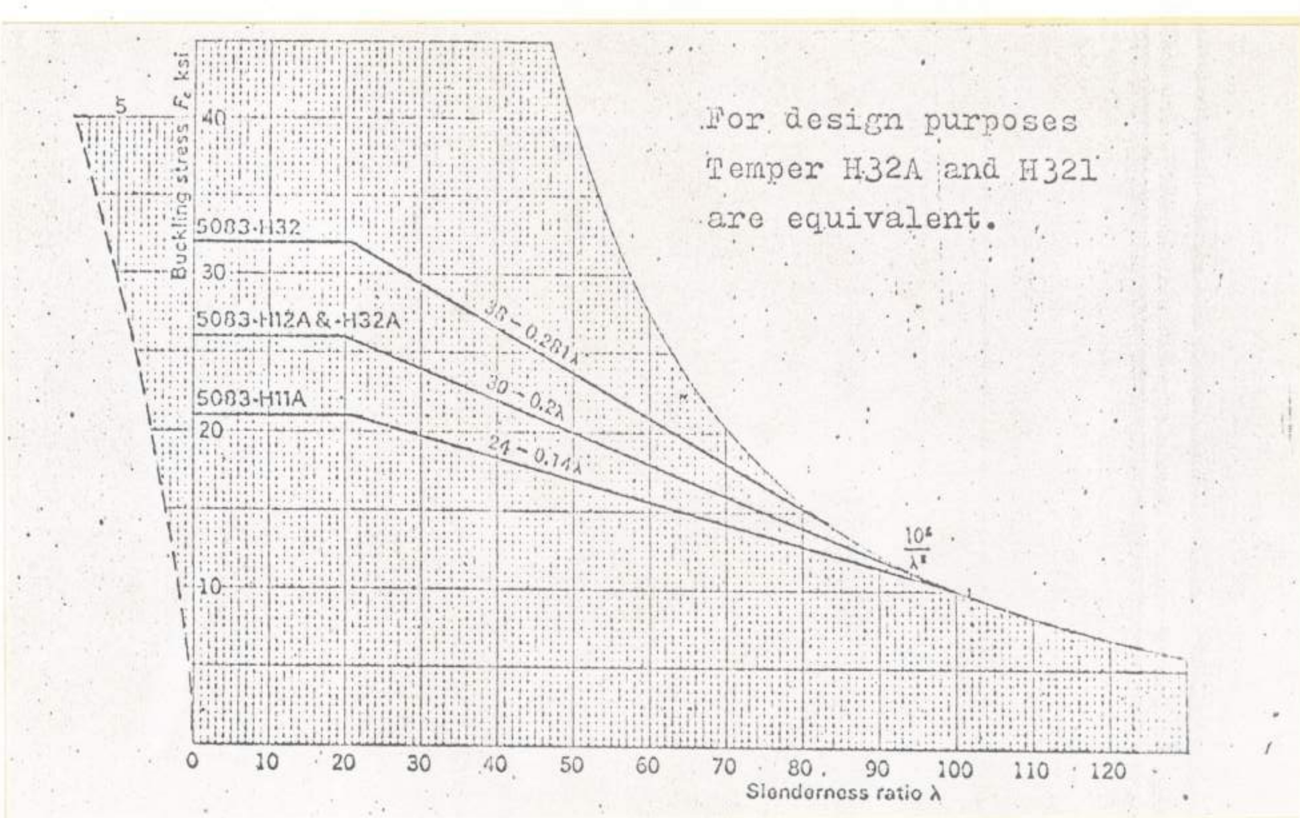


Diagram 2. Buckling diagram for 5083 alloy.

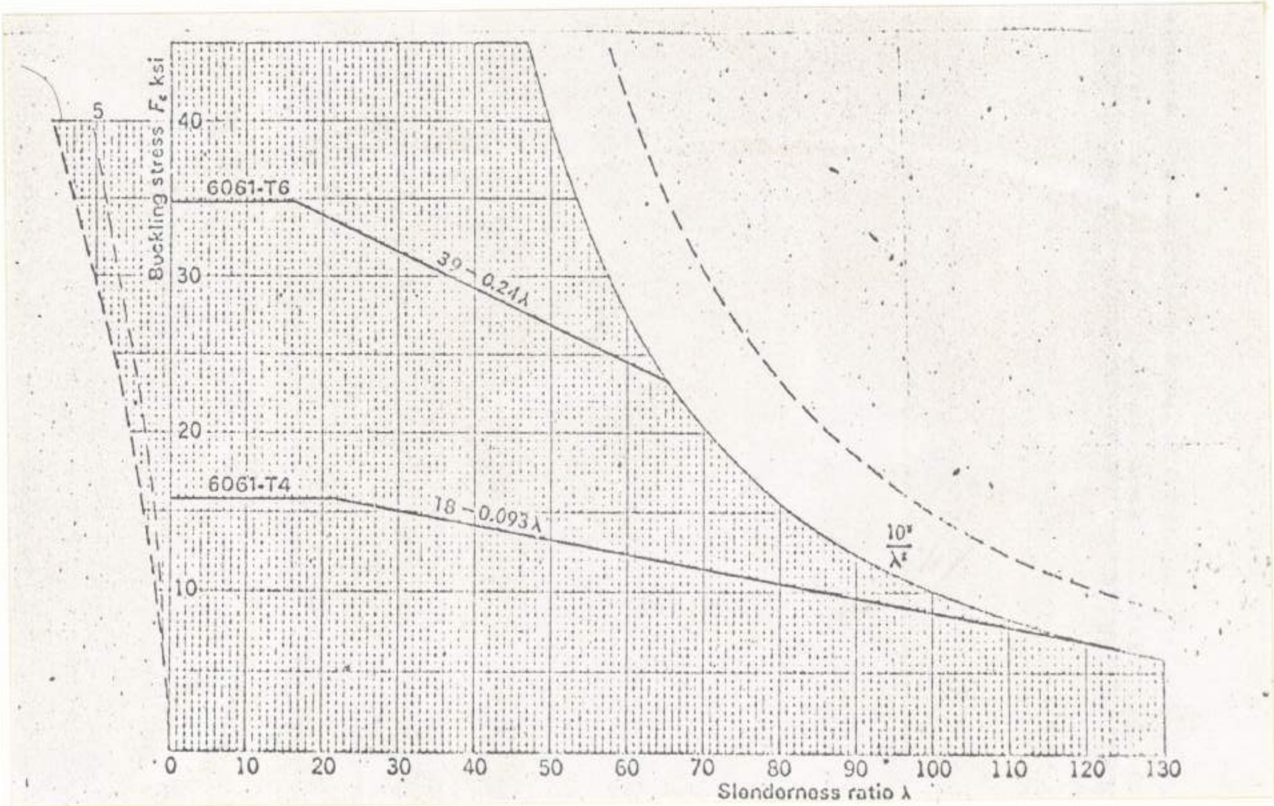


Diagram 3. Buckling diagram for 6061 alloy.

DESIGN CONSIDERATIONS

The fundamentals of stress analysis for welded aluminium alloy structures on the basis of the strength of the individual parts or members is essentially the same as for other engineering materials.

However when designing an aluminium alloy structure, particularly a welded structure subjected to fatigue loads, it is recommended not to follow existing steel designs but to start from the beginning. It may well be said that a successful design in steel need not be successful in aluminium alloy, but a successful design in aluminium alloy, will also be successful in steel.

Usually where loads are applied to an assembly or transferred within the assembly difficulty is encountered. The only general rule that can be given is that every load and transfer of load must be fully accounted for and that continuous load paths must be fully resolved. Simplicity of design facilitates this process and leads to more accuracy in design calculations and also lower production costs.

The main difference between design in mild steel and aluminium alloy welded structures is that the fatigue strength of welded joints in aluminium alloy is lower than for mild steel when compared with their respective static strengths. The fatigue strength of welded aluminium alloy, however, is quite adequate to enable welded dynamic aluminium alloy structures to be designed with equal performance to mild steel and high tensile steel structures and give substantial weight savings, which is often the reason for choosing this light material.

After a member has been designed for strength considerations, attention should then be given to any other factors that might dictate an increase in the size. This is particularly true in the case of members that are very lightly loaded in service and hence might not be sufficiently sturdy to withstand handling in the shop, or accidental loadings which might occur during assembly or in service.

In some fields of steel design, arbitrary standards have been set up limiting the size of members with respect to slenderness ratio, width-thickness ratio, width-length ratio, etc. When designing in aluminium alloy, in fields where such standards have been set up for steel, it is advisable to consider how much standards might apply to the aluminium alloy assembly. No general rules can be laid down here for all types of engineering design, but the experienced designer should not completely ignore conventional good practice in these respects.

Successful design is also dependent on a clear understanding of the physical and mechanical properties of the aluminium alloys selected, particularly when the parent metal has a higher strength than the weld. Of these properties, the most significant are those given by the stress/strain curve. i.e. strength, elasticity and elongation, the three properties which determine, in varying degrees, the ultimate load a structure can carry.

In all cases, aluminium and its alloys exhibit an elastic range where the stress strain curve is straight and a plastic range resulting in curvature of the stress strain curve. Unlike mild steel, aluminium and its alloys do not exhibit a definite yield point as shown in Fig. 2. The limit of the elastic range is measured by the 0.2% proof stress and for convenience this is described as the yield strength. The 0.2% proof stress is that stress which will cause permanent elongation of 0.2% of the original length of the metal under consideration after the stress has been released. The slope of the straight part of the curve is described as the modulus of elasticity or Young's Modulus E. For all practical purposes its value may be taken as 10 000 000 lbf/in^2 regardless of the alloy and temper.

Aluminium alloys can be divided conveniently into two groups; "heat-treatable" alloys which respond to thermal treatment to give increased strength, and "non-heat-treatable" alloys, the strength of which may only be increased by cold work. Heat-treatable alloys will, of course, respond to work-hardening and are frequently cold worked after heat-treatment to give higher strengths than could be obtained by heat-treatment alone. The non-heat-treatable alloys may also be given heat-treatments, such as annealing and stabilizing, which do not increase their strength.

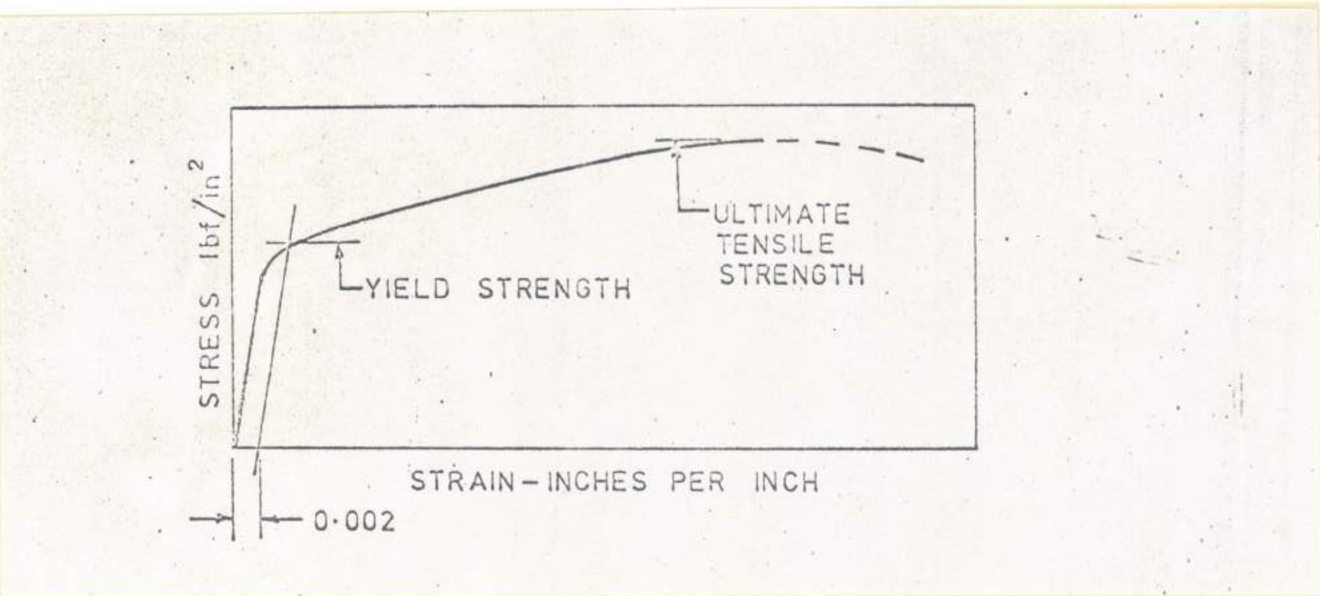


Fig. 2. Typical stress-strain curve for Aluminium alloys.

Both groups of alloys are supplied in various tempers, to give characteristic structure and mechanical properties. The temper designation being dependent on the condition produced in the alloy by mechanical or thermal treatment.

Welding of both "heat-treatable" and non-heat-treatable alloys, other than when in the annealed condition, causes a loss of strength to occur in the heat affected zone of the weld, and this must be taken into consideration in design.

The strength of the heat-affected material in the vicinity of a weld has a minimum value in a narrow zone adjacent to the weld. Outside this zone, the strength increases until it reaches the strength of the "unheat-affected" parent metal at a distance that may conservatively be taken as one inch on each side of the weld, for welds made by the M.I.G. process. If part of the cross section of a welded member is not affected by the heat of welding, as is frequently the case for longitudinally welded members, the material adjacent to the weld is reinforced by the higher strength, "unheat-affected" material at a greater distance from the weld. The tensile strength of such a part can be calculated as the weighted average of the tensile strength of the material in a zone adjacent to the weld and the tensile strength of the material outside this zone.

If F_e is the effective strength of the member in lbf/in^2
F is the unwelded strength of the parent metal in lbf/in^2
F_w is the welded strength of the heat affected zone in lbf/in^2
A is the total cross sectional area of member in in^2
A_h is the area of heat affected zone in in^2
then F_e is given by :-

$$F_e = F - \frac{A_h}{A} (F - F_w)$$

If the area of the heat affected zone is small compared with the total area then the strength of the member is hardly affected by the welding. (refer Note 1 page 6).

F_e F and F_w may be ultimate or yield strength.

Normal factors of safety may be applied to F_e ultimate and F_e yield to obtain a static design stress. The influence of longitudinal welds on buckling stress may be disregarded. The reduced-strength zone is measured from the centreline of the weld for butt welds and from the heel of the fillet for fillet welds.

For transverse butt welds, the tensile strength of an undressed butt joint is equal to the strength of the heat affected parent metal immediately adjacent to the weld bead. In compression where a transverse butt weld is not associated with buckling, then the design stress may be as for tension.

If the transverse butt weld is at the centre of a column, or across an unsupported plate, the failing stress due to buckling should be based on the buckling curve of the welded material using the welded yield stress.

In the case of heat-treatable alloys, and in particular the fully heat-treated 6000 series, the loss of strength due to welding is dependant on several factors which include the welding process used, size of welded assembly and rate of heat input etc. On the assumption that the heat sink provided by the rest of the welded assembly is large enough to ensure a rapid quench of the weld, then the strength in the weld area will approximate the T4 condition since this is the mechanism for obtaining this temper i.e. heating to high temperature (approx. 500°C) followed by a rapid quench.

In the case of non-heat-treatable alloys, all the effects of strain hardening will be removed and the alloy can be considered as reverting to the fully annealed condition irrespective of the welding process, size of weld assembly or rate of heat input etc. From this it follows that where a structural weld must have high strength then an alloy should be selected which has the appropriate strength in the annealed condition. The most widely used alloy for sheet and plate in welded structural assemblies is 5083, and is usually associated with extruded shapes in 6061 or 6351 alloy.

Heat-treatable alloys require a post weld heat-treatment to bring the heat affected zone back to the strength of the parent metal, whereas non-heat-treatable alloys require some form of cold working, such as local yielding in the heat affected zone, to cause some strain hardening to take place to increase the weld yield strength.

An advantage of this loss of strength in the heat affected zones of aluminium alloy structures over similar steel structures is that it is not unusual for some local yielding of welds, due to the weld affected zone yield being lower than the parent metal yield, to occur on the first heavy load application without damaging the structure. (This is contingent on there being no cracks in the welds at the points of local yielding). A heavy load application has the affect of relieving residual stresses created during welding, thus allowing each member of the structure to perform its function as designed.

The elongation required in the metal to permit sufficient stress relief by yielding is of the order of 3%, a requirement met by all structural aluminium alloys. All discontinuities act as stress raisers and although they may be disregarded in static structures they must be examined in dynamic structures where fatigue is of importance.

FATIGUE

In practice, it is possible for an aluminium alloy member to fail under repeated stress applications, even though the maximum stress is well below the static strength of the material. Failures under these conditions are known as fatigue failures and result in the metal fracturing. Fatigue fractures generally appear brittle even though the metal may be quite ductile under static tests. For fatigue failure to occur, some component of the stress must be tensile.

The fatigue behaviour of an aluminium alloy component is dependent on the mechanical properties of the material, the detail of the component itself and the nature of the environment. Stress concentrations play a dominant role as fatigue life is dependent on the peak stresses at points of stress concentration, rather than on the nominal stresses used in ordinary static design. Aluminium alloys exhibit a marked preference for fatigue nucleation in surfaces, consequently surface finish and surface stresses are very influential. When a fatigue failure occurs in a structure, it is almost always traceable to some stress raiser such as a notch, hole or sharp reentrant corner. Concentrations of stress at such points can frequently be alleviated by proper design, fabrication and maintenance, resulting in greatly improved fatigue life. Environment is of importance because there can be interplay between corrosion and fatigue. Fitting of a surface can reduce the fatigue life of a member. Where there is direct contact between surfaces under pressure as in bolted and riveted joints, motion, even of the order of elastic strains, can result in fretting, which can be a factor in the fatigue mechanism.

As a general rule it can be assumed that well-fabricated bolted or riveted joints will not require fatigue consideration up to about 100 000 cycles, whilst 20 000 cycles would apply to welded connections.

Aluminium alloys have not bee shown to exhibit a true fatigue limit, although the number of cycles before failure can become very large. Reported fatigue limit properties for polished specimens, expressed as the reversed bending stress that the alloy can withstand for 500 000 000 cycles without failure have generally very little use as a direct basis for structural parts. In practice the fatigue life of a structure is determined more by the joint configuration of the connections than by the fatigue limit of the parent metal. For transport applications, involving structures subject to continuous dynamic loads, the adopted levels of stress, based on results obtained from practical tests on the particular joints involved (*), are as shown in Table 9 for the indicated alloys.

* Reference: Strength of Aluminium, by Aluminium Company of Canada Ltd., First, Second and Third Editions.

TABLE 9. FATIGUE STRENGTHS OF A6061, B6351, B5083, A5454, A5052

TYPE OF STRESS	1 000 lbf/in^2
Stress in parent metal :	
As produced	8
At butt welds (beads on) and longitudinal fillet welds	3
At transverse fillet welds	2
At stitch welds and other discontinuities	1.5
At bolted or riveted butt joints, on net sections	3
Stress in fillet welds :	
Continuous	2
Discontinuous	1.5

The fatigue strengths shown are based on 10 x 10^6 cycles and well fabricated joints. Poorly fabricated joints such as undercut or poor weld bead contour will result in lower fatigue strengths.

Inertia forces resulting from the gravitational forces acting on the moving vehicle in the vertical, longitudinal and transverse directions can be represented as a fraction of the deadweight of the vehicle. The generally accepted 'g' factor for railway freight wagons is 0.25, but codes vary for different commodities.

Forces due to impact such as the coupling up of railway wagons are not usually included in fatigue calculations owing to the infrequency of such happening. They must however be taken into consideration in the design of members.

The general method of calculation to check fatigue, using Table 9, is to first determine the allowable stress in the welded condition, this being the tabulated welded yield stress divided by a factor of 2. The static stress of the member in question is then computed under loaded condition. This value multiplied by the 'g' factor of 0.25 must produce a stress below that shown in Table 9 for the particular joint involved. Further, the sum of this stress plus the static stress must not exceed the allowable stress. (refer Note 2 page 6).

Ideally, welds should be located at points of low stress, such as the neutral axis or a point of inflection, or be longitudinal to the direction of stress in order to affect only a small portion of the cross sectional area. If all welds could be so confined, they will then carry little more than shear stresses, their size being related to these forces, and they will have minimal influence on the overall strength of the parts they join. This however is seldom if ever completely possible and therefore the basic structural joints are considered.

From Table 9 it will be seen that if a weld across the direction of stress is unavoidable, an unreinforced butt joint gives the best performance for fatigue life. However with some alloys and tempers there is a marked undesirable reduction in tensile strength when transverse welded. The static strength of such joints can be increased by reinforcing the joint with a splice plate. The cross sectional area of the splice plate should be proportioned to make up the loss of strength due to the transverse weld and the length of the splice should be such that the welds in longitudinal shear are as strong as the increase in strength by adding the splice.

Splice plates introduce stress concentrations and hence reduce the fatigue strength of the joint. A diamond shaped splice plate with welds run past the points of the plate as shown in Fig. 3 is the best splice for fatigue loading, as the weld seals the faying surfaces and reduces the peak shear stress in the fillet welds.

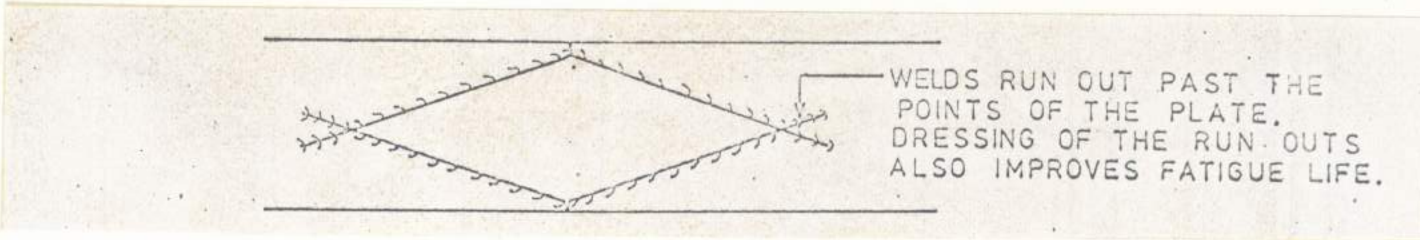


Fig. 3. Splice plate reinforced butt joint.

Lap joints, where used, should lap each other by at least 3 times the plate thickness and be fillet welded at both edges, as shown in Fig. 4, to resist bending due to the eccentricity of this type of joint.

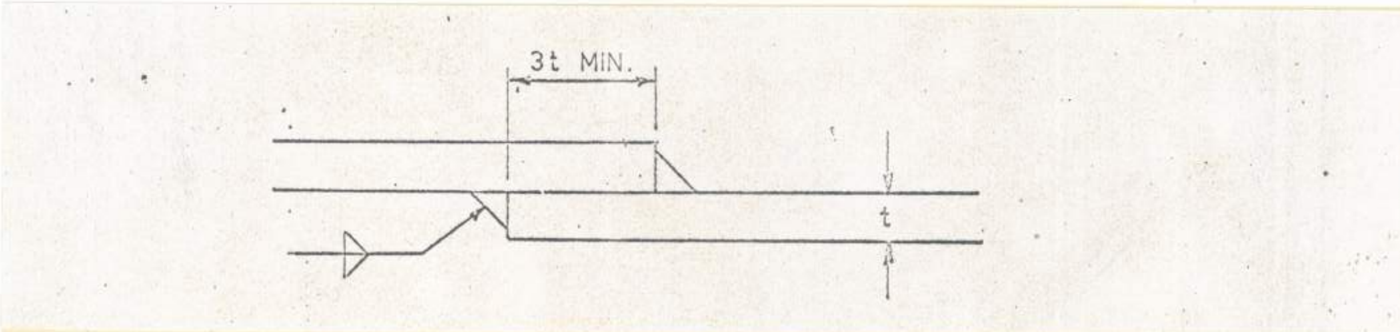


Fig. 4. Lap joint.

Tee joints, where used, should have a fillet weld each side as shown in Fig. 5, to resist any flexing at the weld. Where possible in design one plate should project at least twice the plate thickness to provide adequate metal for the fillet weld also the strength of the outer edge of this plate will be free of weld craters and of greater strength than the weld.

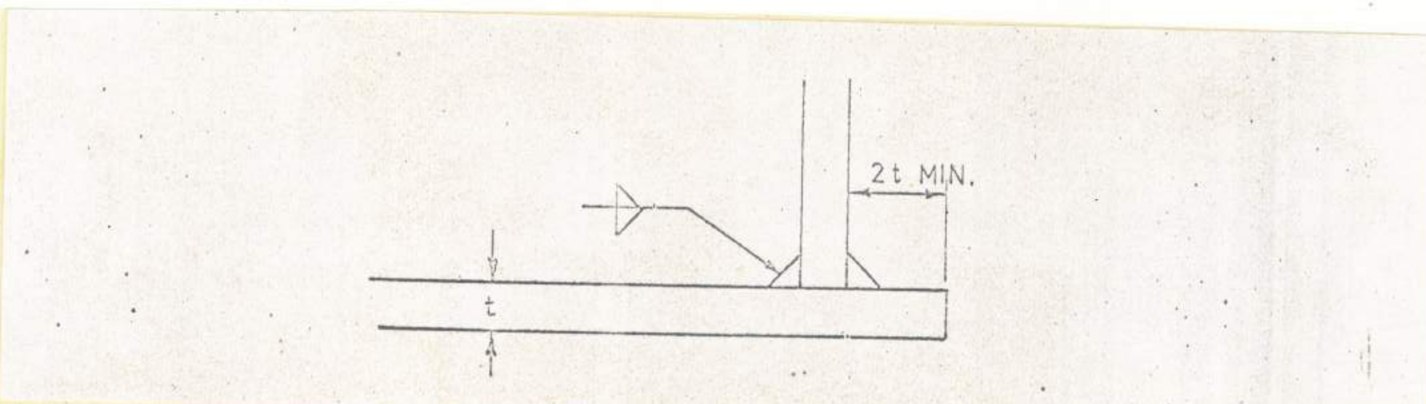


Fig. 5. Tee joint.

Accessibility of weld locations is another important aspect of design affecting fatigue. It is essential that if quality welds are to be made, the size of the welding torch in the MIG process will need to be considered, so that joint details and weld sequences do not make access to some joints difficult or impossible, thereby causing weld defects, such as lack of fusion or penetration, which can considerably reduce the fatigue strength of the joint.

Only duty in the field will provide the final answer to the success of a design from the fatigue aspect. It follows therefore that the final solution is a combination of design and practical experience.

USE OF SPECIAL EXTRUDED SHAPES

The design of an aluminium alloy structure should not necessarily be dictated by standard extruded shapes, except perhaps in the case of a small one off job. Consideration should be given in design to the need of a new extruded shape for a specific application rather than making do with the existing standard shapes.

BOTTOM DISCHARGE DOORS - ORIGINAL DEVELOPMENT, MOCK-UP AND TESTS

Being a bottom discharge wagon, the success of the wagon depended on the design of suitable bottom discharge doors and operating gear. The door design was therefore developed first before proceeding with body design. This steel door design is shown in Fig. 6. (The XC wagon has aluminium doors).

Two essential requirements for the bottom discharge doors were :-

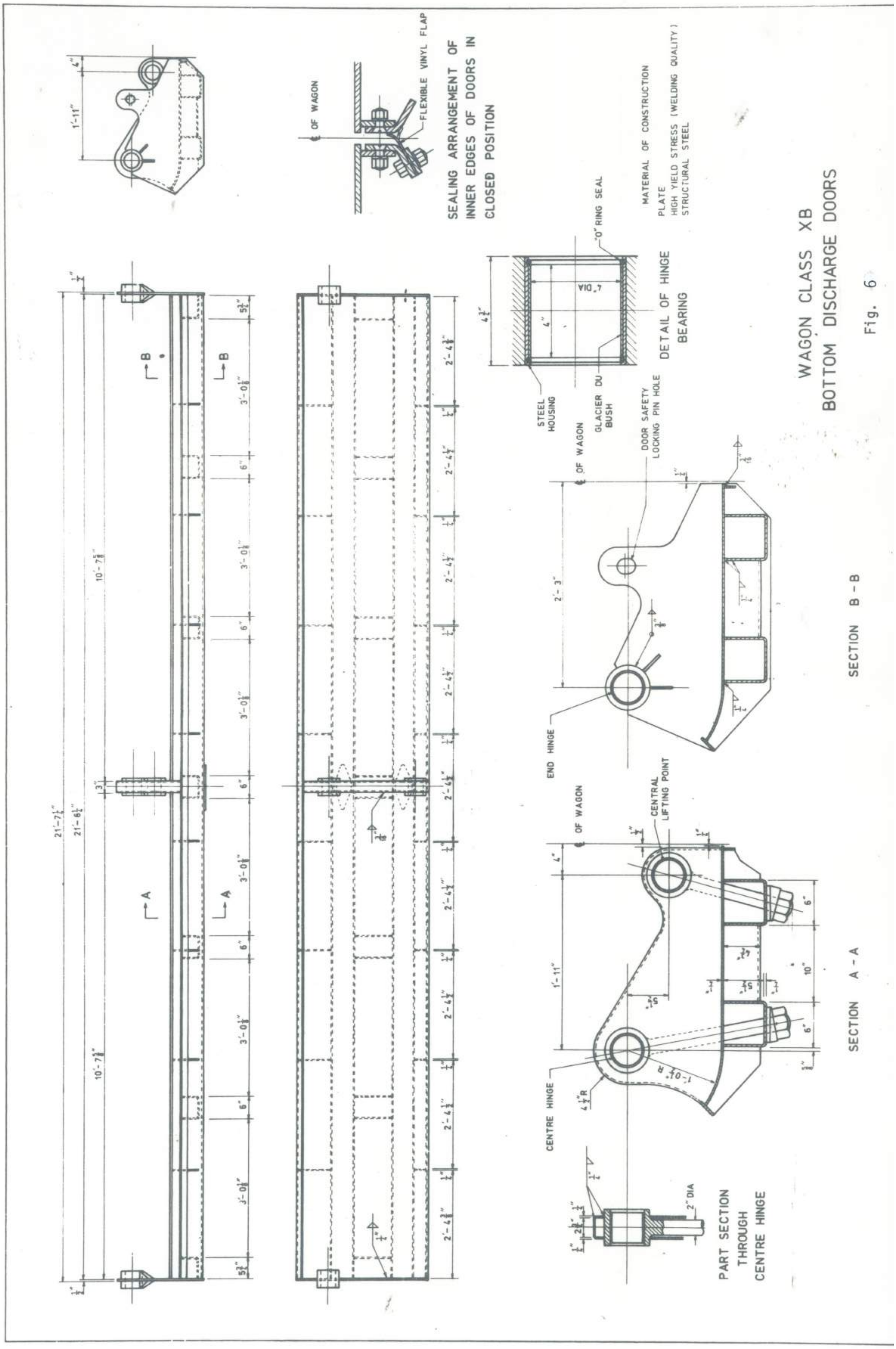
(a) Adequate sealing of doors to prevent spillage of bauxite, which from the crusher at the mine site, could vary in size from 1" particles down to a fine powder. (screened 1" mesh)

(b) Ease of opening and closing in service.

The size of the doors, each approximately 21'-6" long x 2'-11" wide, and the flexibility of the door member in relation to the wagon body between empty and loaded conditions, precluded the use of close fitting components to provide door sealing. Hence the door to body clearance at the ends and along the outside edges of the doors were purposely designed to be greater than the largest particle size so as to eliminate the possibility of pieces of bauxite jamming between the wagon body and the door during opening of the doors in the loaded condition. To seal these large clearances a lip, higher than the corresponding bottom edge of the body, was built into the outside edge of the door to form a labyrinth type seal, as shown in Fig. 7, so that during loading, the bauxite tending to flow through the door clearances will, due to its tacky tenacious characteristic, self choke off any flow. Sealing of the mating inner edges of the two doors was achieved by the use of a flexible vinyl strip flap, as shown in Fig. 6, so arranged to bend either up or down depending on which door closed first, to make a seal irrespective of the closing order of the doors.

The size of the doors also dictated that power operation was essential for speed and ease of operation in service. Double acting air power cylinders, using compressed air piped down the train from the locomotive, were therefore employed to actuate centrally located over-centre locking linkages designed to ensure that when the doors were closed, the load would not be released until the linkages were pulled back over centre by the air cylinders. Photo 9 shows the elements of the operating mechanism as finally fitted to the wagon, in the door closed position and Photo 10 shows the mechanism in the door open position.

A manually operated safety locking mechanism, consisting of a horizontal sliding pin passing through a hole in each door end plate was provided so that should a failure of the door power operated over centre linkage occur when in the loaded condition, the doors will not drop open and discharge the lading onto the track to cause a serious derailment.



WAGON CLASS XB
BOTTOM DISCHARGE DOORS

Fig. 6

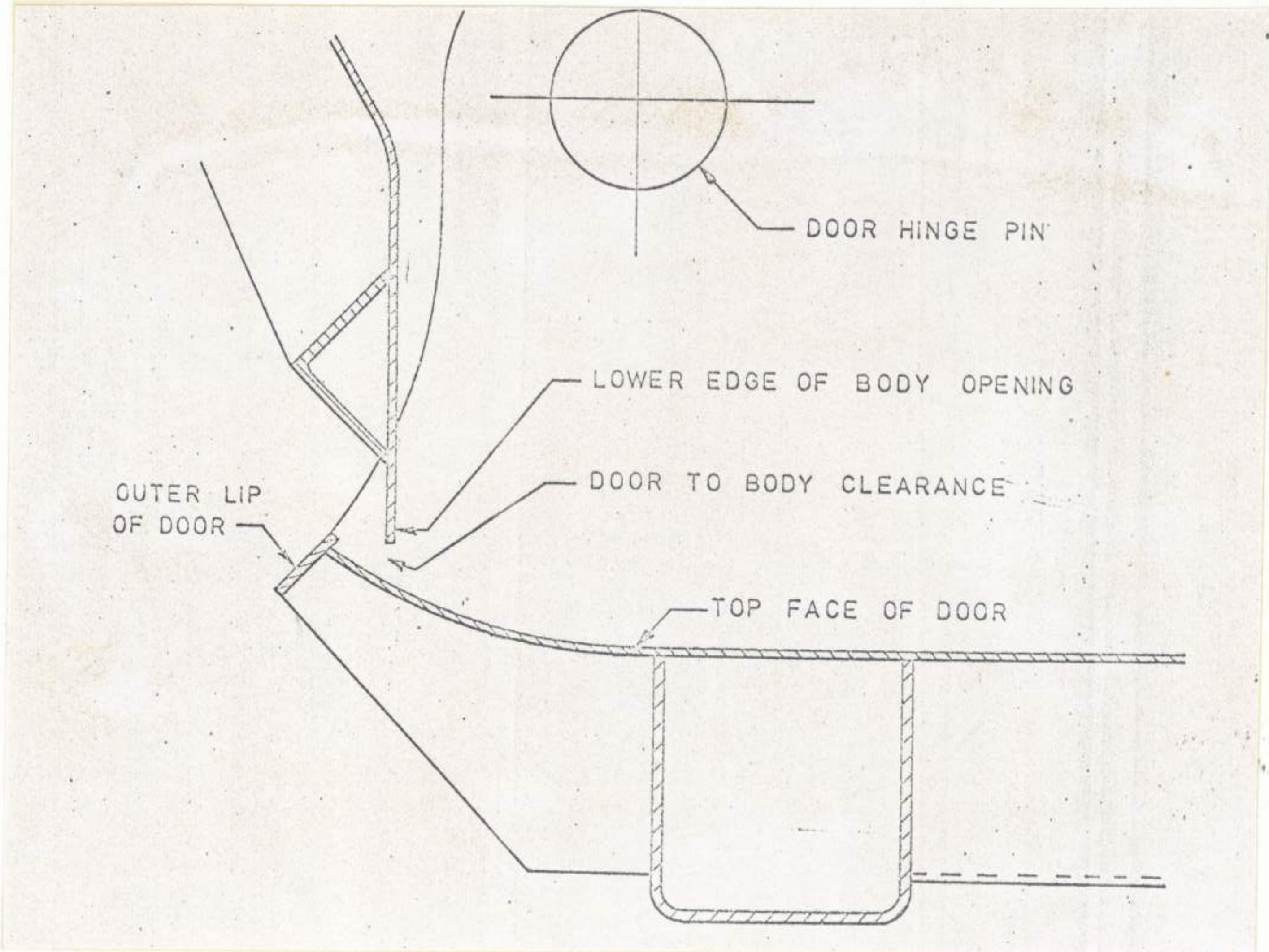


Fig. 7. Labyrinth type sealing between body and door.

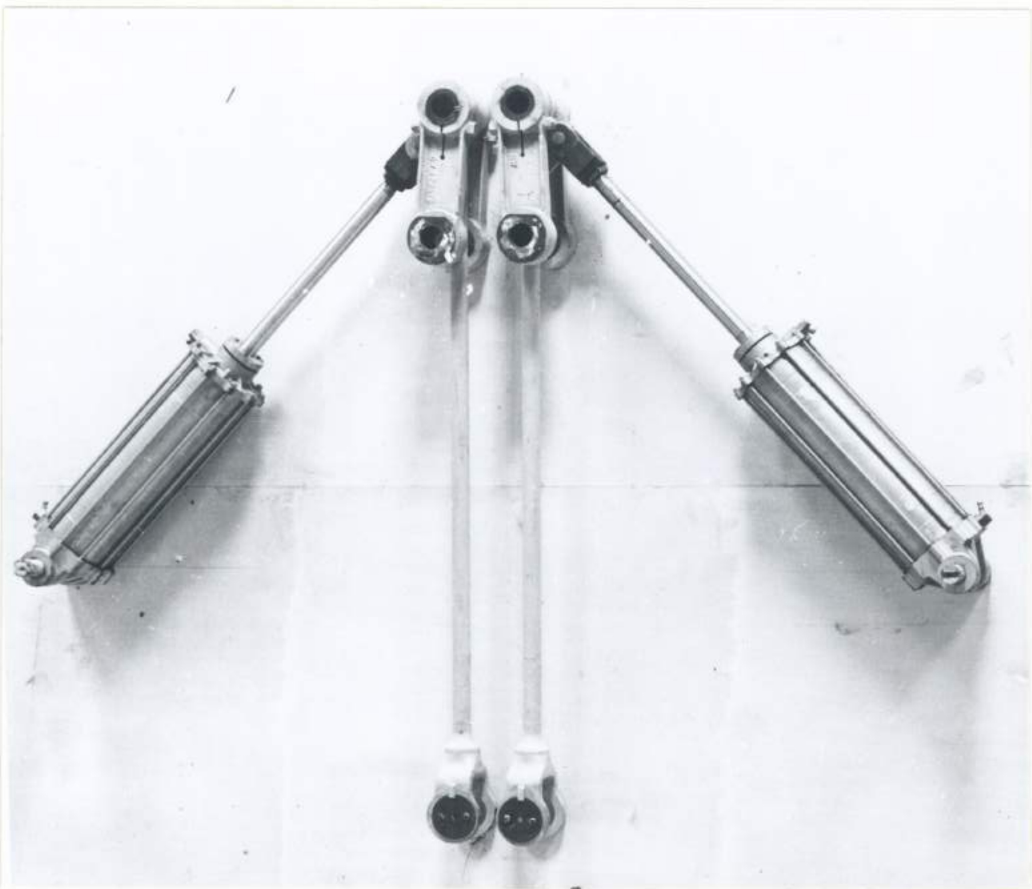


Photo 9. Door linkage in door closed position.

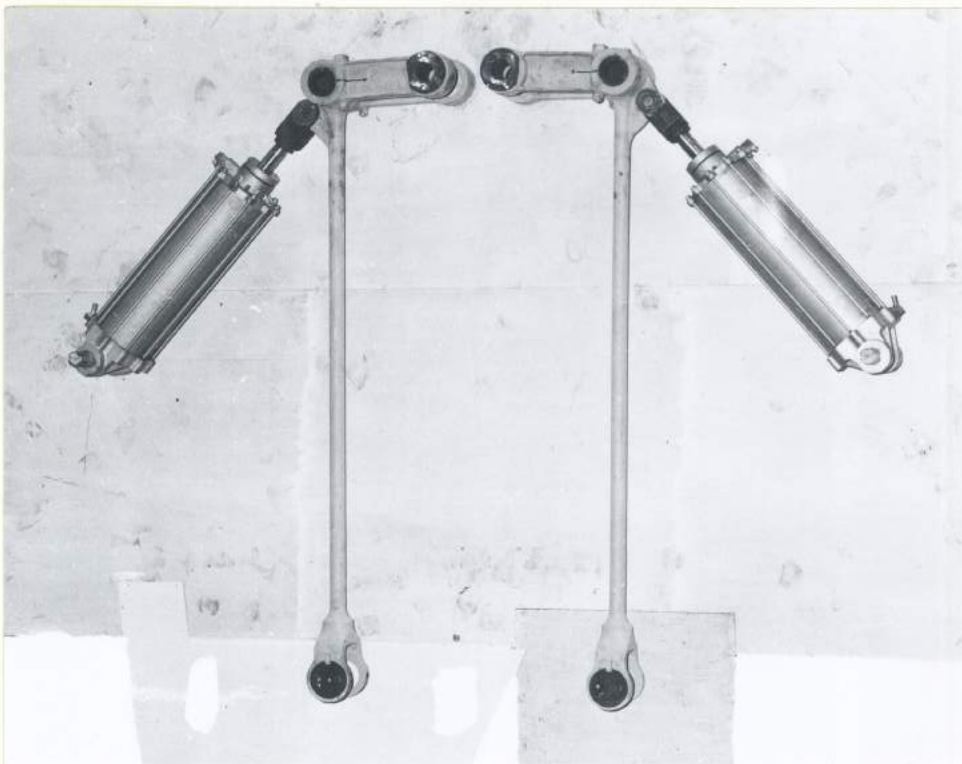


Photo 10. Door linkage in door open position.

DOOR TESTS OF MOCK-UP.

Because the wagon and door design concept was entirely new, before finalising the body design, a full size wagon hopper and door mock-up was constructed in mild steel to prove the door design and operating gear, check the door deflections and hence stresses under actual loading conditions and the hopper shape was completely self discharging. Photo 11 shows this mock-up as constructed with the doors in the open position, the heap of bauxite on the ground having just been discharged.

On the mock-up, each door operating mechanism was actuated by a 6" dia. double acting air power cylinder, all door hinge and linkage pivot bearings were of steel on steel.

Test loadings of the mock-up, using a mobile crane and grab to load 65 ton of bauxite from a height such as to simulate the compaction occurring under a normal loading operation from the overhead storage bins at the mine site, were conducted to determine

(a) Door deflections under loaded conditions

(b) Air pressure in cylinders to open the doors under loaded conditions for

  (i) dry bearing surfaces

  (ii) bearing surfaces lubricated with moly-disulphide grease.

(c) The self-discharging of the hopper.

(a) Door deflections, were measured by means of two lengths of piano wire, under a constant tension, connected between the door end plates and positioned under and in line with the two longitudinal box sections of the door.

The vertical distances between the wires and door members were measured, before and after loading, at 3'-6" intervals along the length of the door. The resultant door deflections are shown graphically in Fig. 8.

Using the door deflections measured, the actual loaded stresses in the door were obtained by determining the minimum radii of curvature along each box section from the equation (*) $R = \frac{L^2}{8}$, where R = radius of curvature in inches, L = length of beam considered, i.e. distance between points of inflection in inches,   = door deflection in inches over distance L.

The minimum radii of curvature occurred in the centre of the door and were R_0 = 15 900 inches at the outer box section and R_i = 10 600 inches at the inner box section.

* Reference: Applied Mechanics for Engineers, by Duncan. Chap. 8.

Photo 11. Full size wagon mock-up for proving wagon concept.

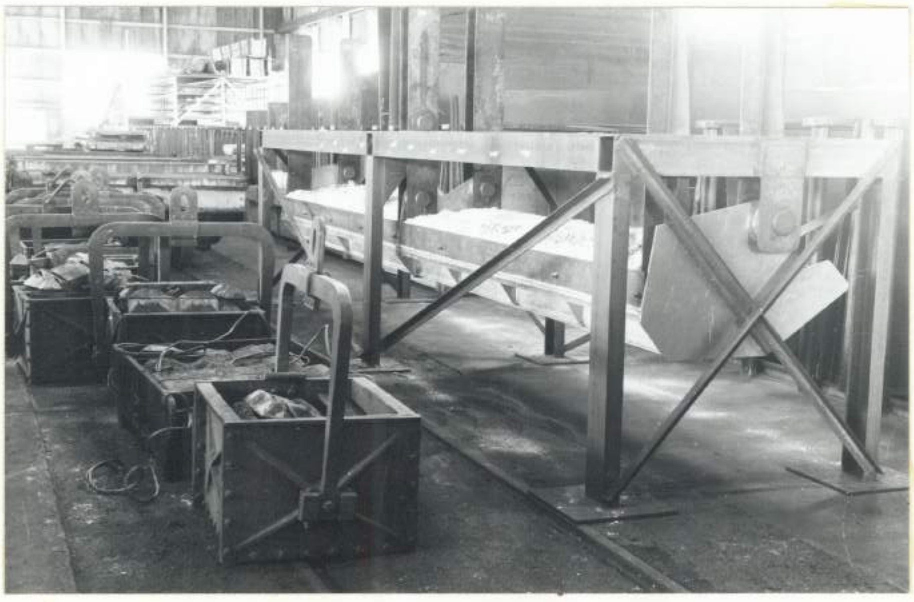


Photo 12. Prototype door mounted in test frame.

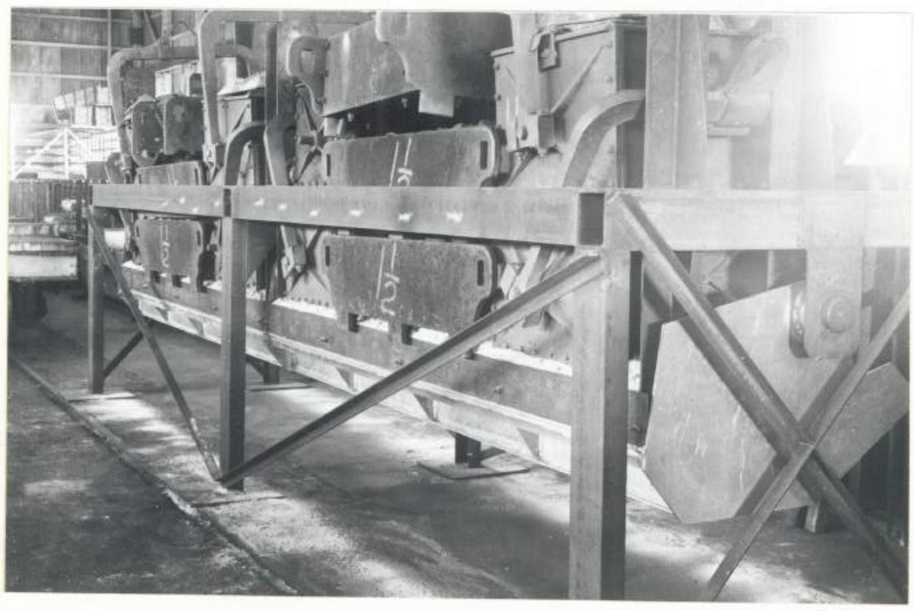


Photo 13. Prototype door with 18 ton test load.

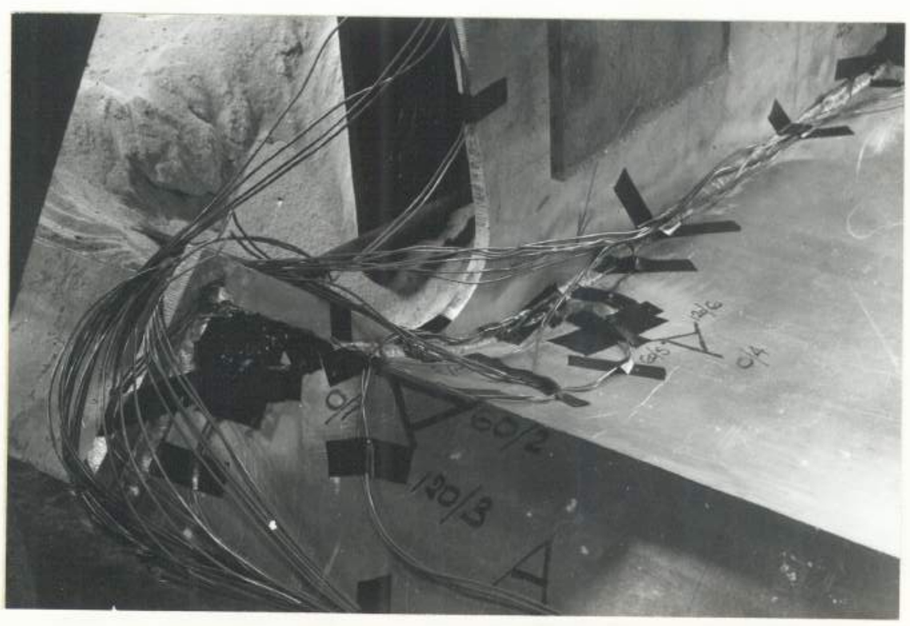


Photo 14. Typical strain gauge application.

Photo 15. Typical strain gauge application.

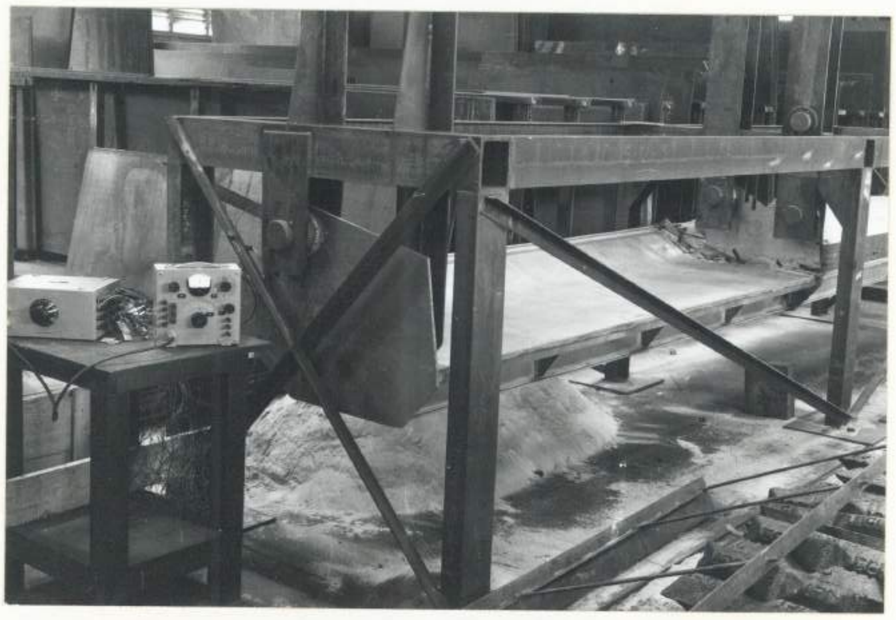


Photo 16. General view of door after application of strain gauge

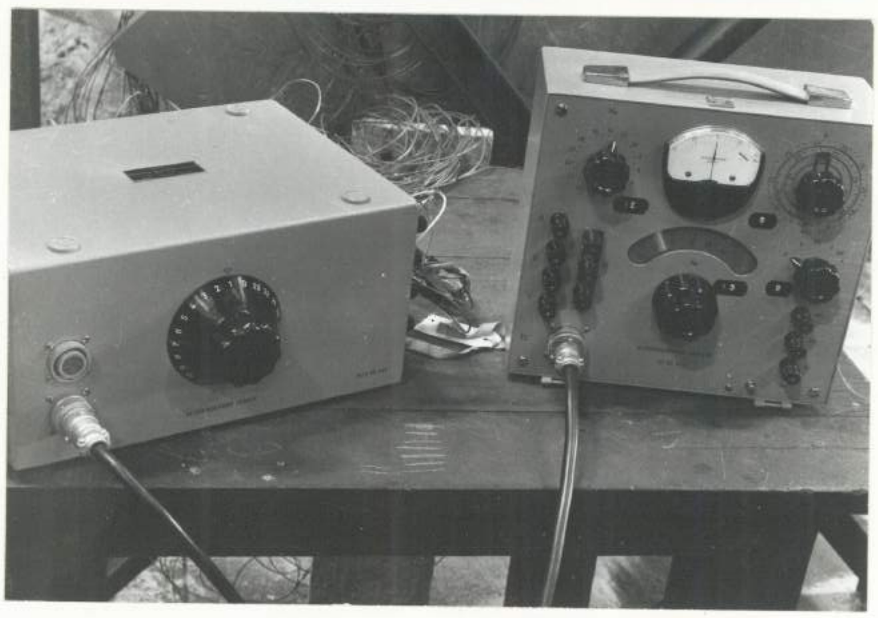


Photo 17. Strain indicator and switching box.

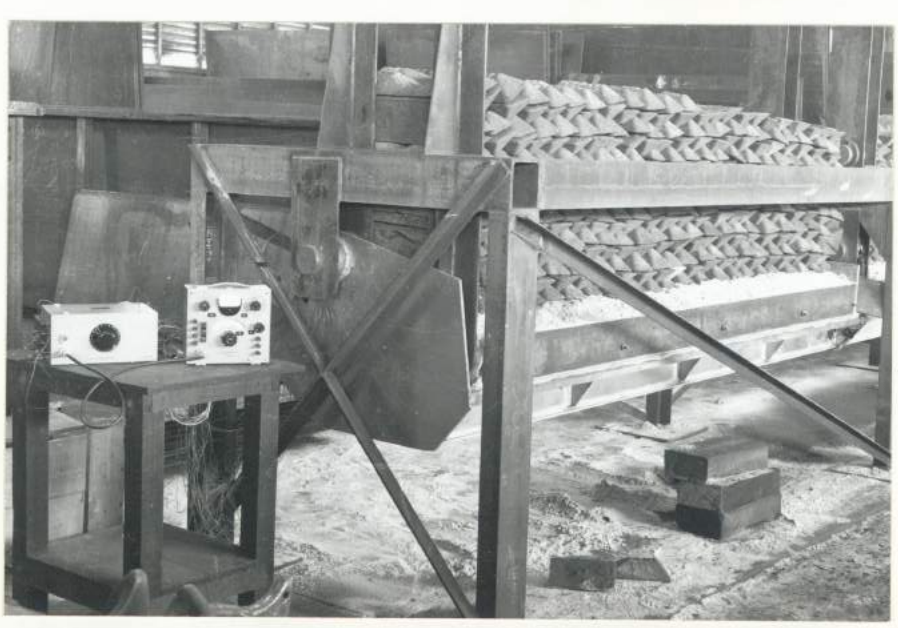


Photo 18. Door loaded with 10.5 ton test load.

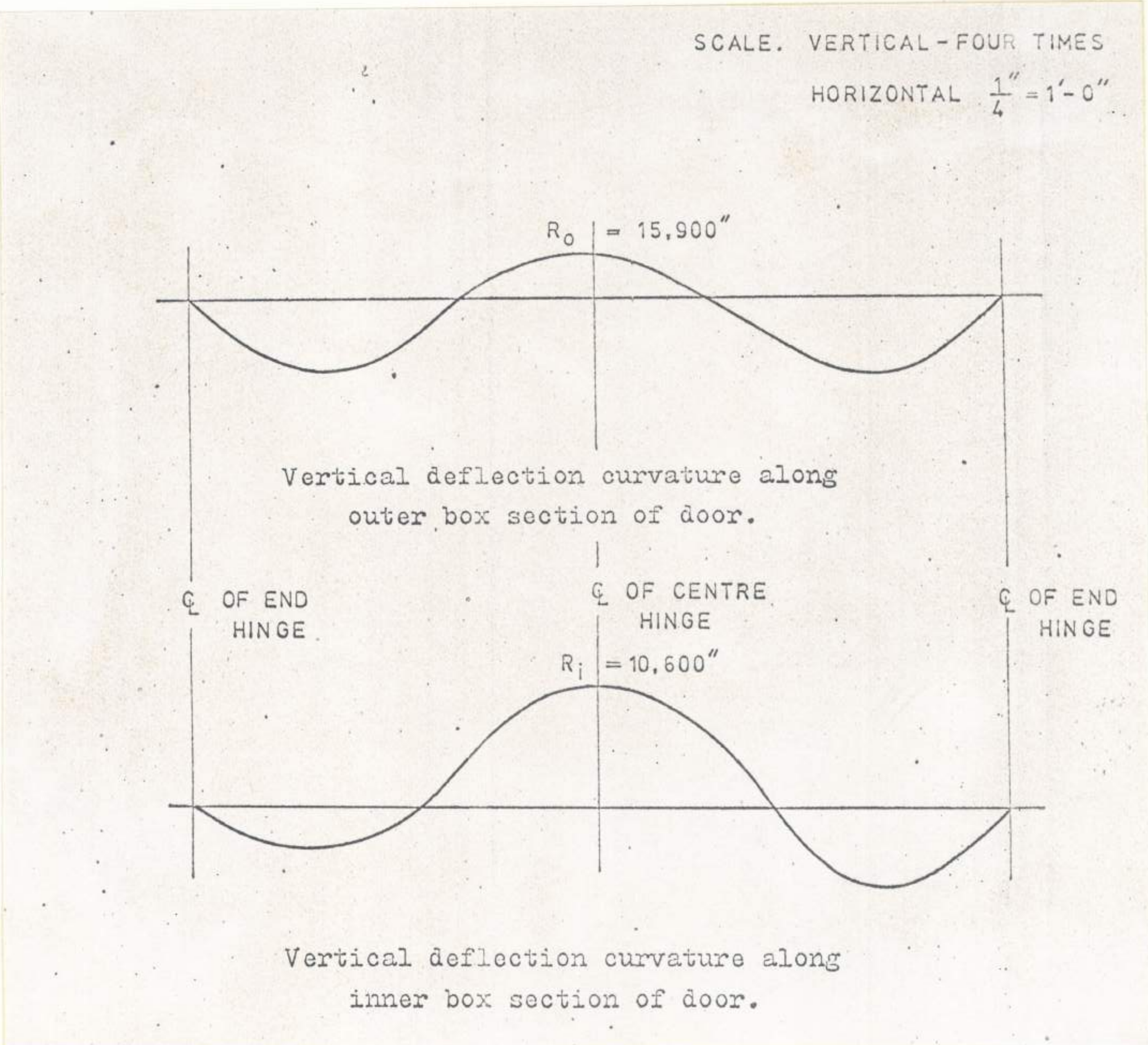


Fig. 8. Vertical deflection curves of door under loaded conditions.

Then based on $f = \frac{Ey}{R}$

where $E = 30 \times 10^6$ lbf/in^2

y_t = 2.26 inches

y_b = 3.74 inches

R_o = 15 900 inches

R_i = 10 600 inches

For R_o

$$f_t = \frac{30 \times 10^6 \times 2.26}{15\ 900} = 4\ 260 \text{ lbf/in}^2$$

$$f_c = \frac{30 \times 10^6 \times 3.74}{15\ 900} = 7\ 050 \text{ lbf/in}^2$$

For R_i

$$f_t = \frac{30 \times 10^6 \times 2.26}{10\ 600} = 6\ 400 \text{ lbf/in}^2$$

$$f_c = \frac{30 \times 10^6 \times 3.74}{10\ 600} = 10\ 600 \text{ lbf/in}^2$$

DOOR STRESS RESULTS AND DATA ON BEARINGS.

A comparison of calculated and test stress results indicated that the stresses in the doors are well within design limits under normal working conditions, as shown in Table 10.

TABLE 10. CALCULATED AND TEST STRESS COMPARISONS

STRESS	CALCULATED STRESS LBF/IN^2 AT		TEST STRESS LBF/IN^2 AT	
	CENTRE HINGE	CENTRAL LIFT POINT	CENTRE HINGE	CENTRAL LIFT POINT
f_t	8 300	11 550	4 260	6 400
f_c	13 720	19 100	7 050	10 600

The test loadings also showed that the door construction exhibited satisfactory rigidity to maintain hinge bearing alignment and door to door sealing clearances within acceptable limits.

(b) Air pressures required to operate the doors under loaded and empty conditions for dry and lubricated bearings are shown in Table 11.

TABLE 11. DOOR OPERATING PRESSURES.

CONDITION	LUBRICATION	AIR PRESSURE REQD. lbf/in^2	DOOR OPERATION
Loaded	Nil	105-110	to open
Loaded	AP-5 Jet lub	70-75	to open
Empty	Nil	45-50	to close
Empty	AP-5 Jet lub	35-40	to close
Empty	AP-5 Jet lub	15	to open

AP-5 Jet lub is a moly-disulphide grease

Under adverse operating conditions when wear on the bearings reduced the efficiency of the door mechanism, the 6" diameter air power cylinders would not have had adequate reserve of power for operation from the locomotive main reservoir air supply. For this reason 8" diameter cylinders were fitted to provide a reserve of power.

The period of time taken to discharge the 65 ton of bauxite from the mock-up was approximately 15 seconds for non lubricated bearings and approximately 10 seconds for lubricated bearings.

The high utilisation factor expected of these wagons necessitated the door design to incorporate suitable maintenance free type low friction, longlife bearings for the door hinges and door operating linkages. The ideal would have been needle roller bearings which have a high load capacity in proportion to size and can be lubricated and sealed for life, however needle rollers in this application would have resulted in brinelling and early failure due to the bearing being subjected to a high unit loading with vibration. A suitable plain type bearing was the only alternative.

Tests were therefore conducted, on a test rig, to evaluate the suitability of available bearing materials as follows :-

(i) Lubron bearings unlubricated. Table 12.

(ii) Glacier DU bearings unlubricated. Table 13.

(iii) Casehardened and ground steel on steel bearings, lubricated with moly-disulphide grease. Table 14.

The test rig comprised a knuckle joint fitted with bushes of the bearing material under test and a hardened and ground steel pin. The bushes had a nominal bore of 2.125", length of 2.125" in the eye and 1.25" long in each leg of the fork. To simulate actual working conditions, a tensile load was applied to the knuckle joint and the pin oscillated through a 90° arc for the number of times at the loadings shown :-

Test (i)
Lubron on steel.

TABLE 12. LUBRON BEARINGS UNLUBRICATED

Tensile pull Tonf	Bearing pressure lbf/in^2	Average torque to rotate pin lbf-in	Number of oscillations	Calculated
1.81	900	1 240	300	.288
3.62	1 800	1 660	300	.192
5.43	2 700	2 200	300	.168
7.24	3 600	2 800	300	.168

Test (ii)
Glacier DU on steel.

TABLE 13. GLACIER DU BEARING UNLUBRICATED

Tensile pull Tonf	Bearing pressure lbf/in^2	Average torque to rotate pin lbf-in	Number of oscillations	Calculated
1.81	900	580	300	.132
3.62	1 800	800	300	.096
5.43	2 700	1 740	300	.132
7.24	3 600	2 500	300	.144

Test (iii)
Casehardened steel on casehardened steel bearings lubricated with moly-disulphide grease.

TABLE 14. CASEHARDENED STEEL ON CASEHARDENED STEEL BEARINGS LUBRICATED WITH MOLY-DISULPHIDE GREASE

Tensile pull Tonf	Bearing pressure lbf/in^2	Average torque to rotate pin lbf-in	Number of oscillations	Calculated
1.81	900	1 620	100	.372
3.62	1 800	3 080	100	.360
5.43	2 700	4 800	100	.372
7.24	3 600	6 180	# 10	.360

After 10 oscillations, the pin seized and the test concluded.

Due to the high torque to be applied manually, the number of oscillations for test (iii) was limited to 100 at each loading.

The test results favoured either the Lubron or Glacier DU bearing, as no periodic greasing was required. The Glacier DU was selected for its lower value of and stability of the bushings in maintaining a lasting tight interference fit in their housings.

The successful operation of the Glacier DU bearing is dependent on the journal surface having a ground finish (*) better than 16 micro inches C.L.A. (British Standard 1134). To maintain this journal surface finish under the corrosive and abrasive conditions to be encountered, the journal surfaces of the pins were hard chromed and ground and "O" ring seals fitted at each end of the bushes to exclude the abrasive dust.

The incorporation of these features into the wagon design have proven highly successful in that the doors fitted to the first batch of wagons, placed in service in 1963, have required no maintenance to the pins or bushes. In 1971 the doors of several wagons were removed to carry out some derailment damage repairs, and inspection of the Glacier DU bushes and pins revealed that negligible wear had occurred, the bearings had only bedded in after some 8 years of continuous service. After the repair work, the doors were re-assembled into the wagons using the existing pins and bushes.

(c) Self-discharging of the hopper was observed to be incomplete, the bauxite hanging up in the valley angles where the side walls joined the end slope sheets and at locations along the side walls where the vertical stiffeners and side wall slope to vertical sheets intersected. The results of these findings led to the adoption, on the final wagon design, of curved side walls with minimal vertical stiffeners and the addition of formed coving pieces to eliminate undesirable valley angles, i.e. the "cleanline concept".

PROTOTYPE DOOR TEST OF "XC" WAGON:

The prototype door was suspended in a frame and a sand bed 6" deep was provided, as shown in Photo 12, to eliminate local concentrations of load on the door plate. The 18 ton test load can be seen in the left foreground.

Prior to the bonding of strain gauges to the door, a distributed load of 18 tons was firstly loaded on the door see Photo 13, enabling a check to be made for possible weaknesses in design or manufacture, and also allow possible release of some residual stresses created during welding, permitting realistic stress values to be obtained from the strain gauges.

APPLICATION OF STRAIN GAUGES.

To evaluate stresses, 7 single and 5 rosette strain gauges were attached to the prototype door at carefully chosen locations as shown in Fig. 9. Typical gauge applications in the area of the centre support plate are shown in Photos 14 and 15. A general view of the door and test equipment is seen in Photo 16, the sand bed having been removed for the application of the strain gauges and circuits.

Gauges were Philips types PR 9811 (single) and PR 9815 (rosette) electrical resistance strain gauges.

* Reference: Designers Handbook No. 2 (Second Edition), The Glacier Metal Company Limited. P.10.

All gauges were applied in the same manner. First a small area was roughened with carborumdum cloth and then cleaned with trichlorethylene. The rapid hardening cement adhesive was then applied to the door and the back of the gauge. The gauge was then placed in the desired location and covered with a piece of teflon sheet. A pressure pad comprising of a piece of rubber set in a U shaped piece of wood was used to apply equal pressure on each gauge. After the adhesive had fully set, the pressure pad and teflon sheet was removed. The gauge was then waterproofed by wax followed by a synthetic rubber compound. A compensating gauge was similarly applied to a piece of aluminium alloy plate and waterproofed. Lead wires of 10/.010 PVC connecting wire were then run from the compensating gauge (on the compensating plate) and the active gauges (on the door) to a gathering point at the end of the door. The compensating gauge plate was clamped on the door. Twenty feet of lead wire was used for all gauges, irrespective of the gauge location. Each pair of leads were bundled and taped together to avoid possible inductance and capacitance changes. The use of shielded wire leads was not considered necessary because of their short length.

Test equipment comprised of -

One Huggenberger Type 1T 1 Strain Indicator

One Huggenberger 24 position Switch Box.

This equipment is shown connected up, prior to final testing of the door, in Photo 17.

Static Load Test

After all strain gauges were bonded in position, protected, and circuits checked, the sand retaining frame and sand bed (0.5 ton) were replaced and a 10 ton load of pig iron ingots, making a total test load of 10.5 tons, were loaded on the door as shown in Photo 18.

Test Stresses

The rosette strains were converted to stresses using Mohr's circle to derive the principal strains, the principal stresses were then calculated from the equations (*)

$$f_1 = \frac{(\mathcal{E}_1 + \mu\mathcal{E}_2)\,E}{1 - \mu^2}, \qquad f_2 = \frac{(\mathcal{E}_2 + \mu\mathcal{E}_1)\,E}{1 - \mu^2}$$

where f_1 and f_2 = principal stresses

$\mathcal{E}_1$ and $\mathcal{E}_2$ = principal strains derived from Moh's circle

μ = poisson's ratio

E = modulus of elasticity

Shear stress $f_s = \frac{1}{2}(f_1 - f_2)$

The strain for any single gauge was converted to stress by multiplying the strain by the modulus of elasticity for aluminium.

The principal stresses for the 10.5 ton load were then corrected by multiplying by a factor of 1.71 to give the stresses for an equivalent 18 ton load, this being the maximum load imposed on the door by a column of bauxite 9'-0" high.

The test results showing gauge, location, type and stresses for an equivalent 18 ton load, to be read in conjunction with Fig. 9, are shown in Table 15.

* Reference: Elements of Strength of Materials, by Timoshenko and Young. 5th edition Chap. 7

TABLE 15. STRAIN GAUGE TEST RESULTS

GAUGE	LOCATION	TYPE	STRESS lbf/in^2
A	Outer surface of spill coping, at centre support plate.	Rosette	f_1 = 4 020 f_2 = 1 820 f_s = 1 100
B	Top face of door above central longitudinal web, at centre support plate.	Rosette	f_1 = 4 030 f_2 = 2 090 f_s = 970
C	Top face of door near inner edge, at centre support plate.	Rosette	f_1 = 5 480 f_2 = 2 530 f_s = 1 470
D	Vertical face of inner longitudinal box section, near centre support plate.	Rosette	f_1 = 3 330 f_2 = 2 880 f_s = 3 100
E	Under side face of longitudinal box section, below central web.	Rosette	f_1 = 4 850 f_2 = 1 860 f_s = 1 490
F	Centre support plate cut out radius	Single	f = 2 660
G	Centre support plate, side edge of central hinge.	Single	f = 510
H	Centre support plate, top edge of central lifting point.	Single	f = 7 830
J	Centre support plate, side edge of central lifting point.	Single	f = 100
K	Outer surface of spill coping	Single	f = - 300
L	End support plate, side edge of end hinge.	Single	f = 870
M	End support plate, inner vertical face near top of door.	Single	f = 4 350

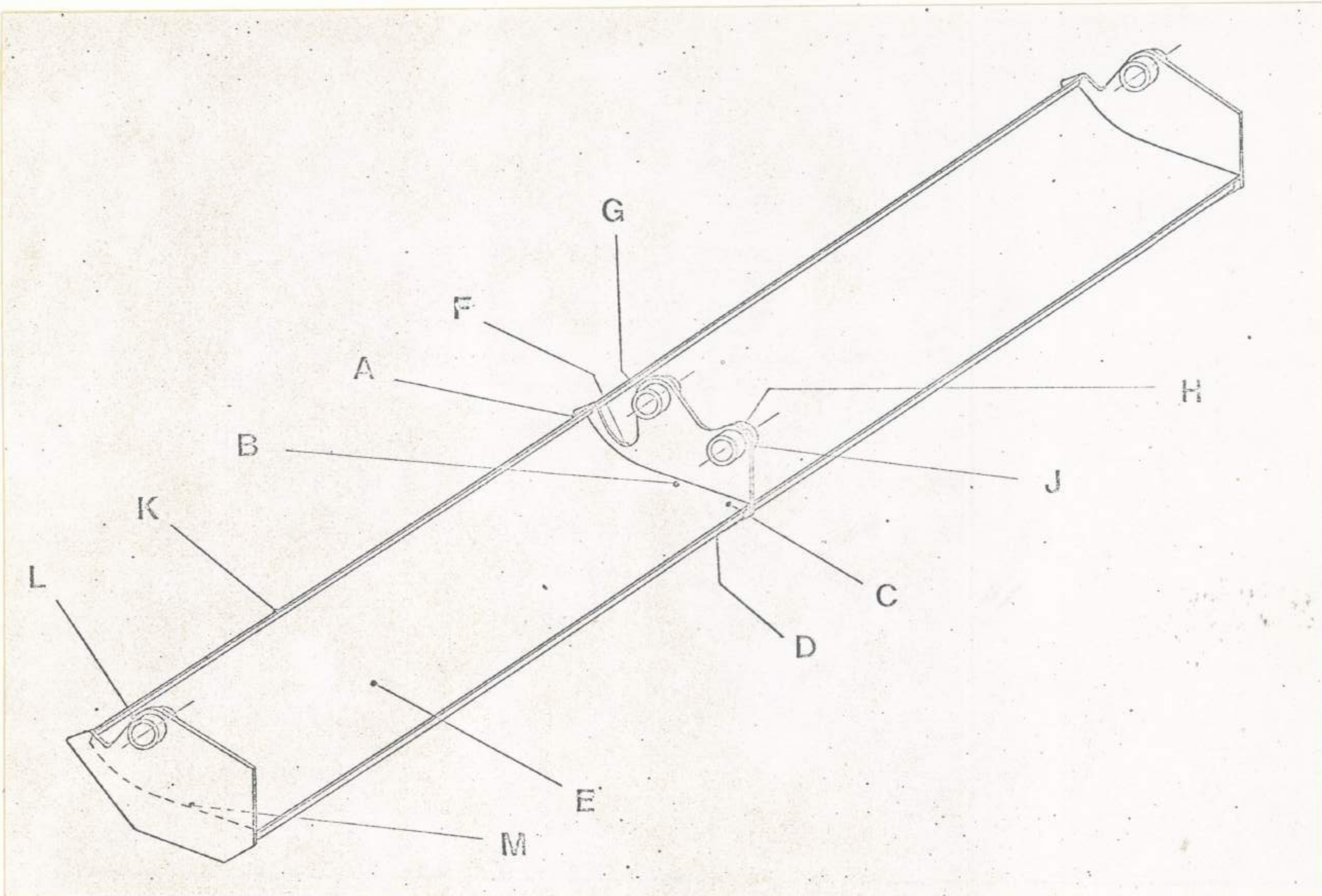


Fig. 9. Location of strain gauges on door.

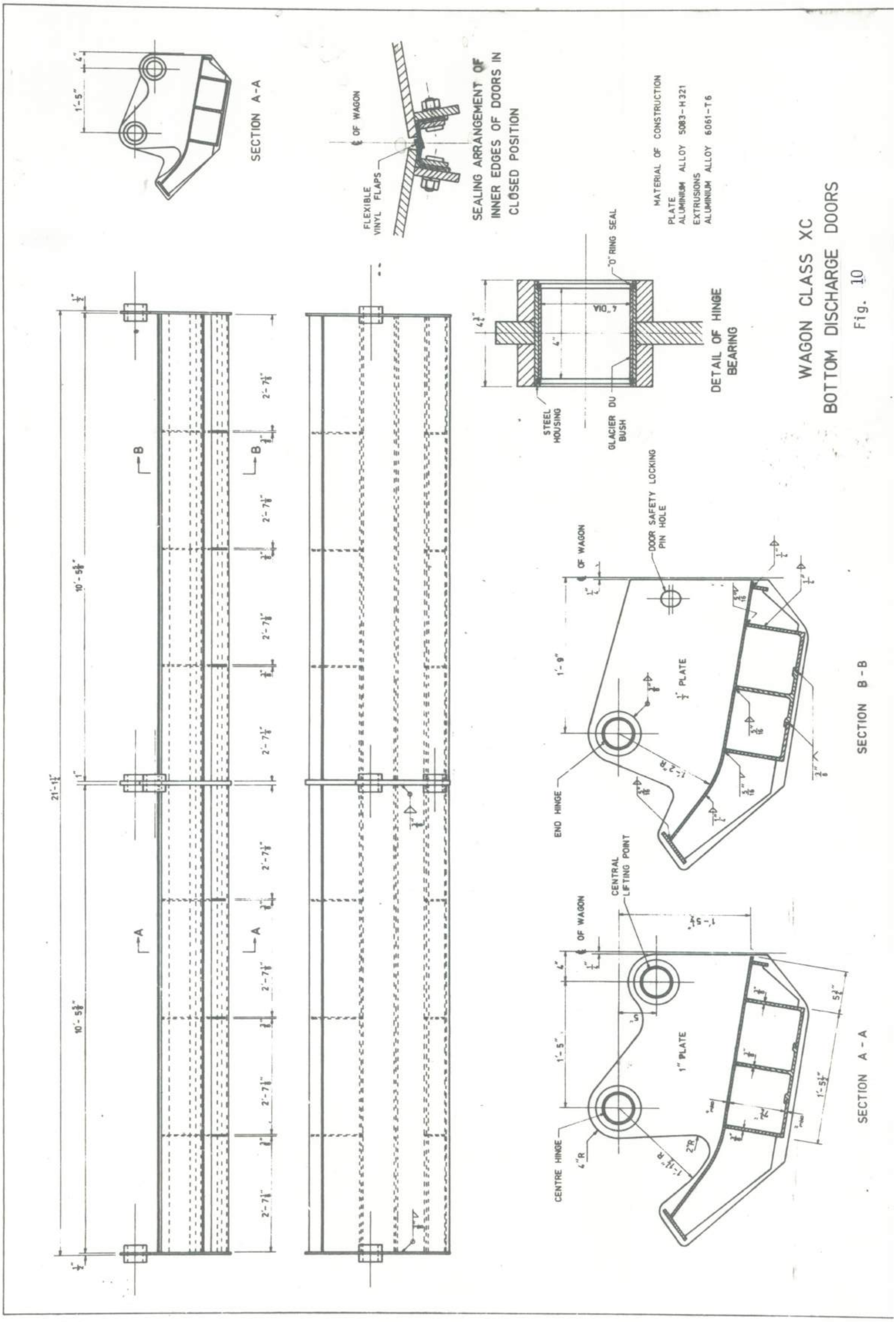
Where f_1 = Maximum principal stress
f_2 = Minimum principal stress
f_s = Maximum shear stress
f = Principal stress in direction of gauge

A positive value denotes tension
A negative value denotes compression

The test stresses in the top plate of the door at the centre support plate agree favourably with the theoretical stresses, indicating that a good design approach had been used. The stress level at gauge H was considered high, so the centre support plate thickness was increased from ½" to 1" thick plate.

Because of the unknown damaging effect of loading, at the No.2 mine site, bauxite greater in size than one inch from a height in excess of 10'-0", on to the door plate, it was deemed advisable to increase the 5/16" thick plate of the prototype to 3/8" for the final door design see Fig. 10, the resulting weight increase being insignificant compared with the extra resistance to denting.

The extruded sections were designed to provide good access for welding with no weld preparation or temporary backing strips required for the butt welds. All welds in the high stress areas are longitudinal except where butted and fillet welded to the end and centre support plates.



WAGON CLASS XC
BOTTOM DISCHARGE DOORS
Fig. 10

DESIGN OF THE "CLASS XC" ALUMINIUM WAGON

WAGON BODY DESIGN CRITERIA.

The introduction of Standard Gauge (4'-8½") railway operations and rolling stock, on the Western Australian Government Railways in 1966, created an awareness in the design staff of the short comings of designing rolling stock to the then existing Australian and New Zealand Railway Code of Practice, (this code has since been revised to conform generally with the standards as laid down by the Association of American Railroads) and for existing standard W.A.G.R. type drawgear capacity limitations.

Therefore, to provide for trains of 10 000 tons on 4'-8½" gauge, designs of rolling stock were based on the requirements of the Association of American Railroads. "Specification for design, fabrication and construction of freight cars". (*)

Policy was also determined that the design strength of all new designs of 3'-6" gauge rolling stock should be such as to allow possible future conversion to 4'-8½" gauge.

In accordance with the above, the all aluminium alloy bauxite wagon structure was designed to meet the following requirements :-

Maximum draw-bar pull	540 000 lbf	Clause 4.2.2.4 300 000 x 1.8 F of S)
Working draw-bar pull	300 000 lbf	Clause 4.1.8
Maximum buffing load applied at one end of car	1 000 000 lbf	Clause 4.1.10.1
Working buffing load	300 000 lbf	Clause 4.1.8

The wagon structure has also to be able to resist a static end load of 800 000 lbf Clause 4.1.9 applied at the rear draft stops without causing any permanent deformation of the structure.

DESIGN OF ALL ALUMINIUM ALLOY WAGON - CLASS XC - GENERAL NOTES

At the time of commencing design of the all aluminium alloy wagon, Alcoa were preparing to move mining operations to their No. 2 mine site. The loading of the wagons would then be carried out in a tunnel, simultaneously loading eight or more wagons at the one spotting of the train. It was therefore essential that the new wagon design be built to the same length over couplers as the existing composite wagons to match up with the wagon loading door centres in the roof of the tunnel.

This meant that to retain the same gross weight on rail of 80 ton and thus obtain the maximum advantage of light weight aluminium alloy construction, the new design would require increased hopper load carrying and hence volumetric capacity, equivalent to the reduction in tare weight of approximately 4.5 ton.

The 4.5 ton weight saving was based on :-

(a) an all aluminium alloy body of monocoque construction, in lieu of the composite steel and aluminium alloy, to give an estimatedweight saving of 3.3 ton.

(b) bottom discharge doors constructed in aluminium alloy, in lieu of low alloy high tensile steel, to give an estimated weight saving of 0.8 ton/wagon

* Reference: Association of American Railroads, "Specification for Design Fabrication and Construction of Freight Cars".

(c) the use of specially designed bogies with integrally mounted brake cylinders and single high friction composition brake shoes (similar to Wabcopac), in lieu of the conventional brake lever type braked bogies with clasp brakes, cast iron shoes and underframe mounted brake cylinders, to give an estimated weight saving of 0.4 ton/wagon. This type of bogie also simplified the wagon body end design.

Because of the low speed of operation in the loaded condition of 35 m.p.h., laid down by the Civil Engineering Branch, the increase in hopper volumetric capacity was achieved primarily by an easement of the maximum allowable centre of gravity from 5'-8" to 5'-10" above rail in the loaded condition for bogie wagons. The design of the new loading tunnel at the No.2 mine site catered for the resulting 9" increase in wagon height.

To avoid having to increase the side wall thickness above 5/16" plate, a reasonable radius of curvature had to be maintained, resulting in a reduction in the width of the bottom door opening in the wagon body from 5'-5" to 5'-0", also to fit bogies with the air brake cylinders mounted integral in the brake beams required an increase in the distance between the axles on a bogie from 5'-6" to 5'-9", which resulted in a reduction in the length of the bottom door from 2'-6.3/4" to 2'-0.3/4". The reduction in the width of the opening made it necessary to redesign the location of door hinge points and hence the door design.

BOTTOM DISCHARGE DOORS.

The criteria and method of operation for the bottom discharge door in aluminium alloy were the same as used for the steel doors (ref page 13 Section 6.)

DOOR LOADINGS.

The door loading was again conservatively taken to be equal to the height of the column of bauxite on the door, being 9 ft., which, at a density of 86 lb/ft^3, produced a unit loading of 774 lbf/ft^2, equal to a total load of 18 ton on each door.

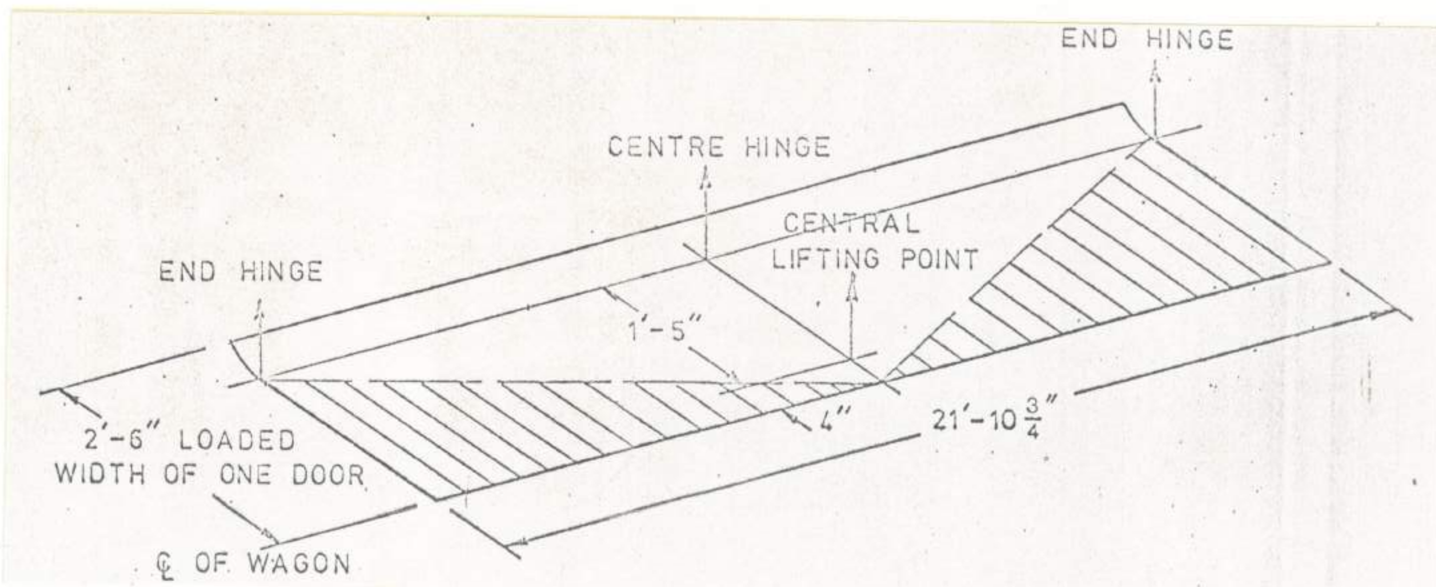


Fig. 11. Door Geometry.

The dimensions of the door varied slightly from the previous steel door, the reduction in width and length and the need to reduce the transverse distance between the hinge and central lifting point assist in reducing the bending and torsional moment on the door. The suspension point locations and door geometry are as shown in Fig. 11.

The support reactions being derived as follows :-

load per door = 21.06' x 2.5' x 774 lb
= 40 630 lb

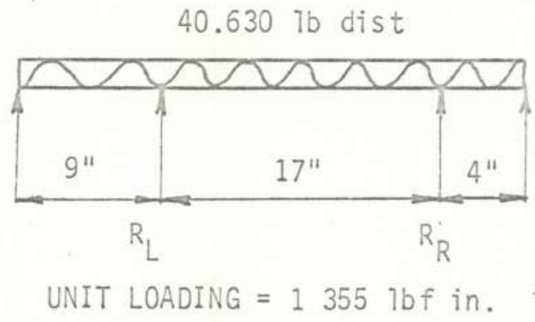
Assuming the three hinge points to act as one in the centre, the centre hinge and central lifting point maximum reactions, based on the 40 630 lb total load being uniformly distributed over the 2'-6" transverse width of door will be :-

M about R_L

$$= -\frac{9^2}{2} \times 1\,355 + \frac{21^2}{2} \times 1\,355 - 17\,R_R$$

R_R = 14 340 lbf at the central lifting point.

and R_L = 26 290 lbf = the sum of end hinge and centre hinge reactions.



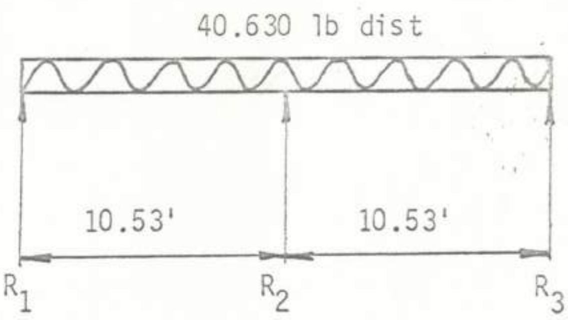
Considering now the centre hinge and central lifting point as one and treating the door longitudinally as a continuous beam on three supports, the hinge maximum reactions using the continuous beam equation will be :-

For centre support reaction.

$$R_2 = 1.25 \times \frac{40\,630}{2} = 25\,400 \text{ lbf}$$

Each end support reaction

$R_1 = R_3$ = 7 615 lbf.



The estimated reaction on the centre hinge point

$R_2 - R_R$ = 25 400 - 14 340
= 11 060 lbf

Summary of reactions are :-

end hinges	=	7 615 lbf each
centre hinge	=	11 060 lbf
central lifting point	=	14 340 lbf

To provide adequate door to door sealing for the aluminium alloy doors, the door deflections under loaded conditions should approximate those of the existing steel door design. To meet this requirement in aluminium alloy, a door section approximately 45% deeper than the existing steel door would give similar rigidity, as to obtain equal rigidity -

$$\frac{\text{moment of inertia in aluminium alloy}}{\text{moment of inertia in steel}} = 3$$

DOOR DESIGN.

As stated earlier, under "Design Considerations", a successful design in steel need not be a successful design in aluminium alloy and this case was considered to be no exception to this rule. Adaption of the steel door design in its present form to aluminium alloy was considered unsatisfactory and a new approach was taken.

The aluminium alloy door design as finally fitted to the wagon, shown in Fig. 10, is built up from a formed top plate and two specially designed extruded sections. The length of the door was divided in two and each half butted against the centre support plate and welded all around, thus providing over twice the length of weld as would be possible with a continuous one piece length door.

To prove the viability of constructing such a sized door in aluminium alloy, a prototype door design was first prepared and fabricated out of plate in alloy 5083 - H11A. The door was then subjected to simulated loaded conditions and stresses checked with strain gauges.

The fabricated door section considered was as shown in Fig. 12.

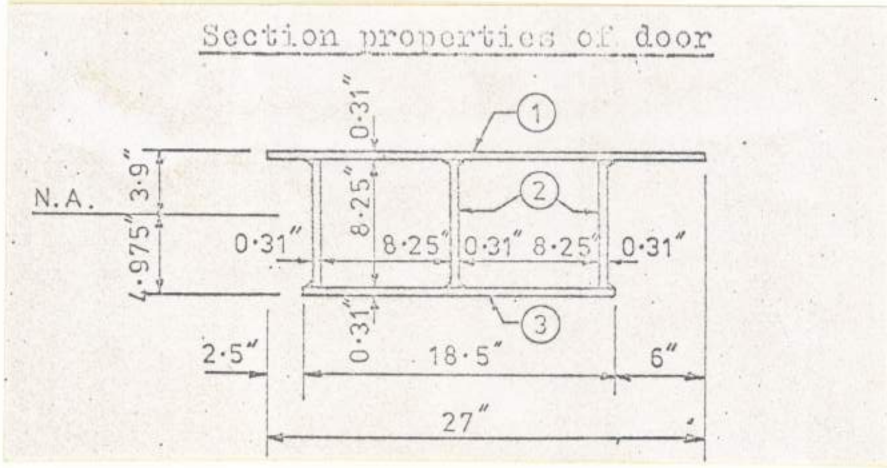


Fig. 12.

Summing moments about top face of door section shown in Fig. 12

ELEMENT	b(total)	d	A	y	Ay	Ay^2	Icg (element)
1	27	0.31	8.37	0.15	1.25	0.2	0.06
2	0.94	8.25	7.75	4.43	34.35	152.2	43.98
3	18.5	0.31	5.73	8.71	49.95	435	0.04
			21.85		85.55	587.4	44.08

$$\bar{y} = \frac{85.55}{21.85} = 3.9''$$

$$I_{xx} = \text{Icg (element)} + Ay^2 - Ay\bar{y}$$
$$= 44.08 + 587.4 = 85.55 \times 3.9$$
$$= 296 \text{ in}^4$$

Door deflections should be within the existing steel design as the moment of inertia for the aluminium alloy door section is over 3 times that of the steel door section without taking into account the slight reduction in the span between supports for the aluminium alloy design.

Considering now the door as a continuous beam on three supports, the maximum bending moment occurs in the door at the centre hinge and central lifting point, and using the equation

$$\frac{wl^3}{2} = M_a l + 4M_b l + M_c l \qquad w = 1\,935 \text{ lbf/ft}$$

$$l = 10.53 \text{ ft}$$

$$M_b = \frac{wl^2}{8} \qquad M_a = M_c = 0$$

$$= \frac{1\,935 \times 10.53 \times 10.53 \times 12}{8}$$

$$= 320\,000 \text{ lbf in.}$$

The stresses at the centre of the door due to this bending moment are :-

$$f = \frac{My}{I}$$

$$f_t = \frac{320\ 000 \times 3.9}{296}$$

$$= 4\ 220 \text{ lbf/in}^2 \text{ (tension on top of door)}$$

$$f_c = \frac{320\ 000 \times 4.975}{296}$$

$$= 5\ 380 \text{ lbf/in}^2 \text{ (compression on underside of door)}$$

The additional stresses due to the effect of the cantilever load considered to act on the area shown shaded in Fig. 36, were calculated by considering each span of the door as a cantilever beam, fixed at the centre hinge and supported at the end of the door, (in line with the end hinge), with a 774 lbf/ft^2 unit loading varying from zero value at the centre hinge to a maximum at the end hinge. The distribution of these additional stresses at the centre of the door, was assumed to be a maximum at the inner edge, diminishing to zero at the outer edge.

$$R_1 = \frac{9wl^2}{40}$$

$$= 3\ 200 \text{ lbf}$$

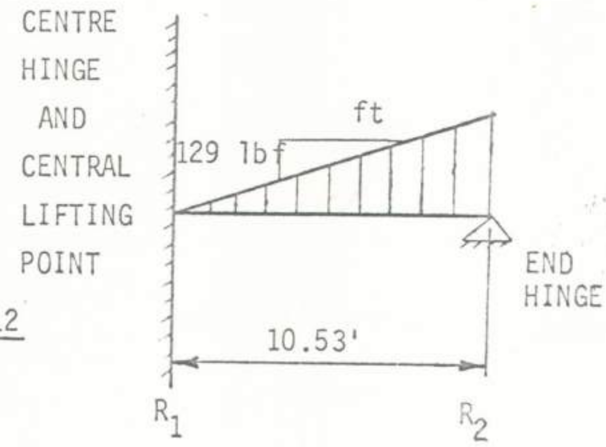
$$R_2 = \frac{11\ wl^2}{40}$$

$$= 3\ 910 \text{ lbf}$$

$$M = \frac{7wl^3}{120}$$

$$= \frac{7 \times 129 \times 10.53 \times 10.53 \times 10.53 \times 12}{120}$$

$$= 104\ 530 \text{ lbf in}$$



$$f = \frac{My}{I}$$

$$f_t = \frac{104\ 530 \times 3.9}{296}$$

$$= 1\ 380 \text{ lbf/in}^2 \text{ tension on top of door}$$

$$f_c = \frac{104\ 530 \times 4.975}{296}$$

$$= 1\ 760 \text{ lbf/in}^2 \text{ compression on underside of door.}$$

$I = 296 \text{ in}^2$
$y_t = 3.9 \text{ in}$
$y_b = 4.975 \text{ in}$
$M = 104\ 530 \text{ lbf in.}$

The maximum resultant stresses, at the inner edge of the central lifting point are :-

$$f_t = 4\ 220 + 1\ 380 = 5\ 600 \text{ lbf/in}^2 \text{ tension on top of door.}$$

$$f_c = 5\ 378 + 1\ 760 = 7\ 140 \text{ lbf/in}^2 \text{ compression on underside of door}$$

To allow for dynamic loading, the above stresses are multiplied by a factor of 1.25.

$$f_t = 5\ 600 \times 1.25 = 7\ 000 \text{ lbf/in}^2$$

$$f_c = 7\ 140 \times 1.25 = 8\ 925 \text{ lbf/in}^2$$

Since the welded strength governs, due to the transverse weld of the door section to centre support plate, the allowable welded strength, in the top for 5083 to 5083 alloy is 10 800 lbf/in^2, and in the bottom for 6061 alloy to 5083 alloy will fall between 8 000 and 10 800 lbf/in^2, possibly in the order of 9 400 lbf/in^2. Both the tensile and compressive stresses are within the allowable.

The fatigue strength for a transverse fillet weld, from Table 9, is 2 000 lbf/in^2. The dynamic component of the above stresses both fall within this limit.

FORCES ACTING ON THE STRUCTURE OF THE WAGON

Static Loading

The weight of the wagon body and lading corresponding to an all up weight on rails of 179 200 lb. is reacted by vertical forces at the bogie centre plates.

Total weight on rails	=	179 200 lb.
Weight of bogies (2)	=	19 700 lb.
Weight of wagon body and lading	=	159 500 lb.

The vertical static reaction per bogie

$$V_s = \frac{159\ 500}{2} = 79\ 750 \text{ lbf.}$$

These loads are shown in Fig. 13.

The above loads will need to be multiplied by a factor of 1.25 to allow for dynamic conditions when the wagon is running at speed.

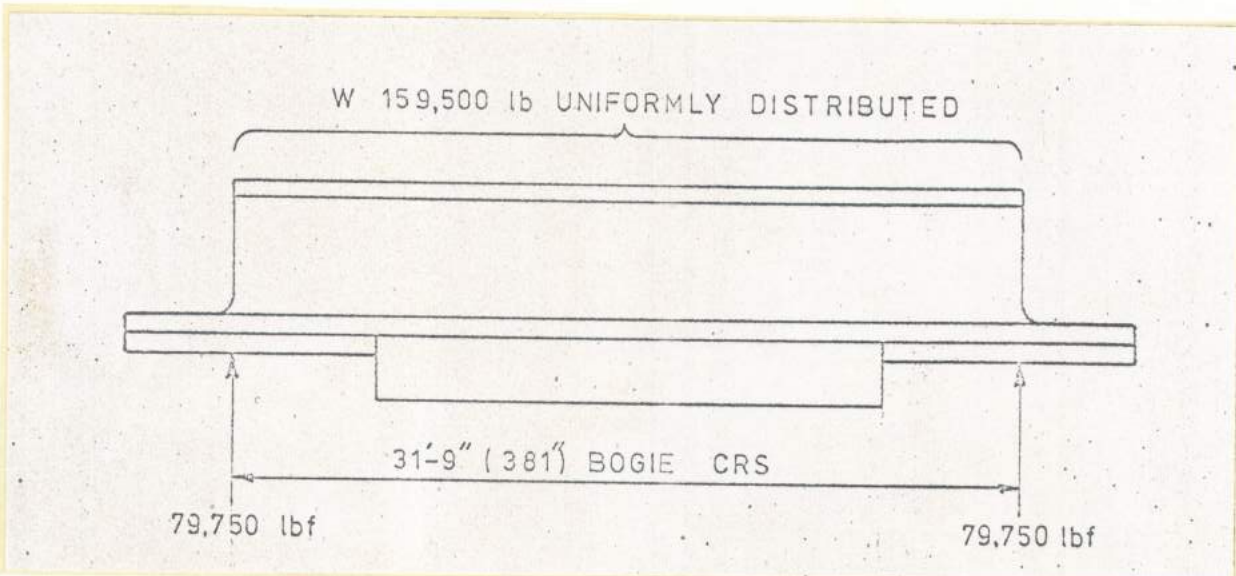


Fig. 13. Vertical Static Loading

Resultant shear force and B.M. diagrams for static and dynamic loading are shown in Fig. 14 and 15.

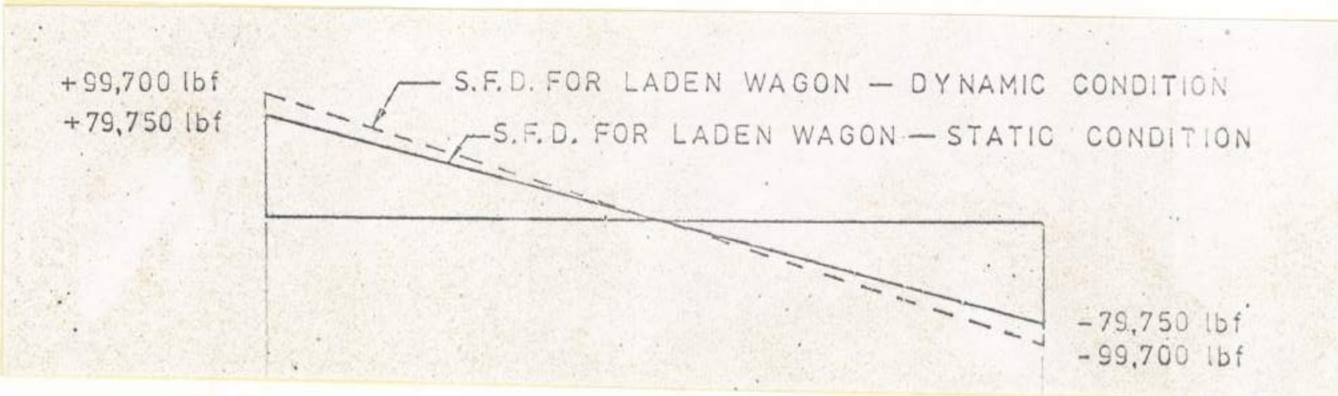


Fig. 14. Shear force diagram for static and dynamic vertical loadings.

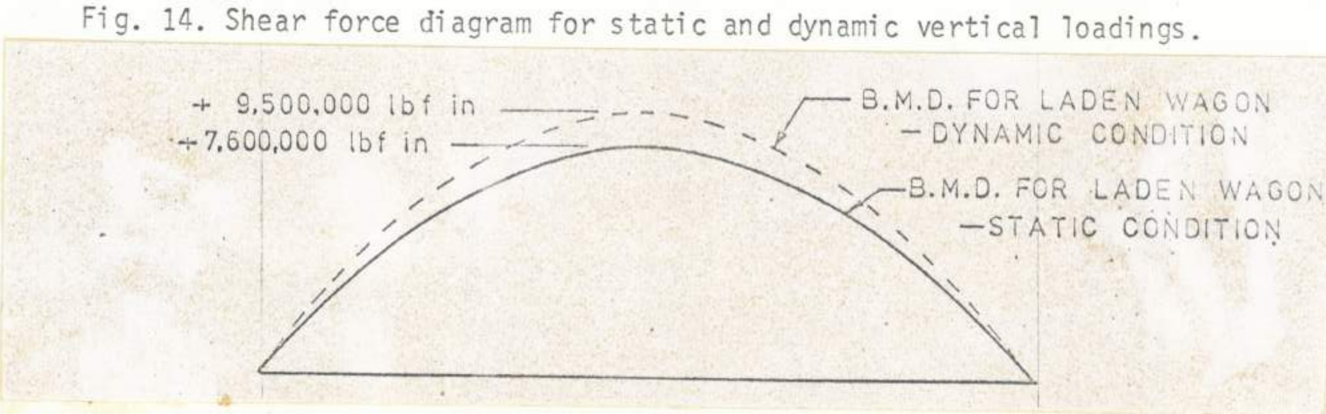


Fig. 15. B.M. Diagram for static and dynamic vertical loadings.

Impact Loading

The maximum buffing load of 1 000 000 lbf is assumed to act through the draft gear at a point 2.45 ft. above rails and is reacted by the inertia of car and lading as follows :-

(1) $\frac{1\ 000\ 000 \times 19\ 700}{179\ 200}$ = 110 000 lbf by the bogies, applied at the front bogie centre plate, 1.72 ft. above rail level.

(2) 1 000 000 - 110 000 = 890 000 lbf, applied by the inertia of structure and lading, acting at 6.4 ft. above rail level.

These reactive inertia forces create a pitching moment M_p, tending to rotate the wagon about the leading bogie.

$$M_p = 890\ 000 \times (6.4 - 2.45) - 110\ 000\ (2.45 - 1.72)$$
$$= 3\ 437\ 000 \text{ lbf ft.}$$

This pitching moment M_p is resisted by moments M_w and M_i due respectively to the weight and rotational inertia of the laden wagon.

The reactive moment due to the weight of the wagon and lading -

$$M_w = 159\ 500 \times \frac{31.75}{2}$$
$$= 2\ 532\ 000 \text{ lbf ft.}$$

The balance of the pitching moment is reacted by the inertia moment of the body and lading mass rotating about the leading bogie -

$$M_i = M_p - M_w = 3\ 437\ 000 - 2\ 532\ 000$$
$$= 905\ 000 \text{ lbf ft}$$

The validity of designing this wagon for a 1 000 000 lbf impact force is doubted, as since M_i is positive, it follows that no vertical load remains on the trailing bogie. The weight of one bogie is 9 850 lb, therefore a trailing wagon will be required to exert a downward force through the coupler to hold the trailing end of the impacted wagon down on the rails for a 1 000 000 lbf impact force.

The equivalent vertical reaction, at the leading bogie, forming part of the inertia couple to meet the 1 000 000 lbf requirement, assuming assistance from a trailing wagon,

$$V_i = \frac{905\ 000}{2/3 \times 31.75} = 42\ 760 \text{ lbf}$$

Total vertical reaction at the leading bogie centre

$$V = 159\ 500 + 42\ 760 = 202\ 260 \text{ lbf}$$

All these forces are summarised in Figs. 16 and 17.

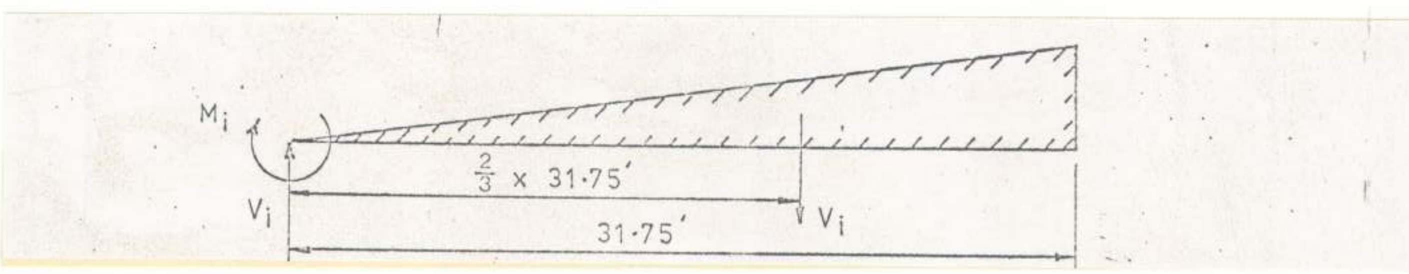


Fig. 16. Reactive moment due to inertia.

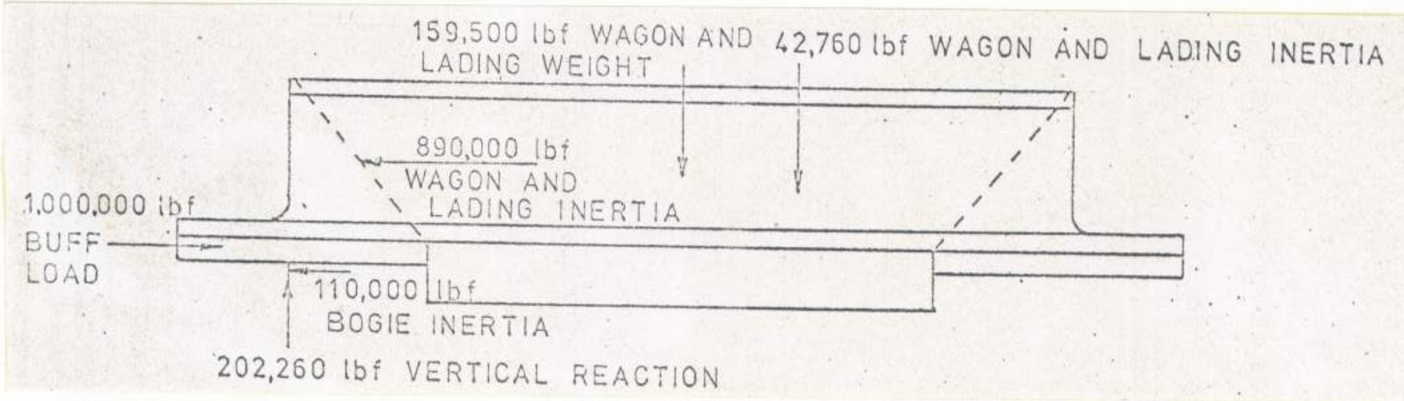


Fig. 17. Impact loading.

SECTION PROPERTIES AND STRESS ANALYSIS.

Static Loading

Considering the side walls of the wagon as a relatively short thin webbed beam resisting the overall bending moment due to the weight of the wagon and lading.

Section properties of the side wall, neglecting that small portion of the side wall below the side sill extrusion, are shown in Fig. 18.

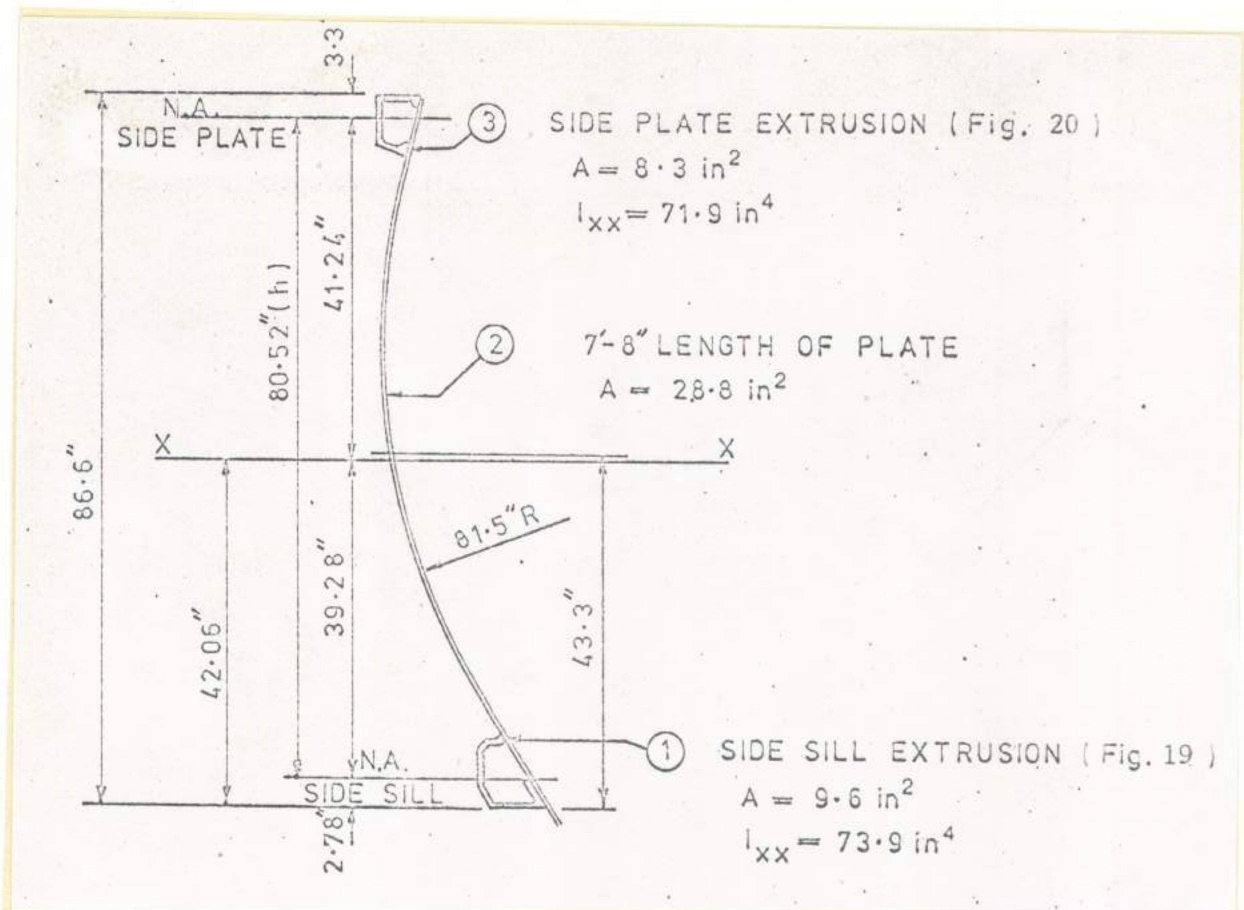


Fig. 18. Effective bodyside section

ELEMENT	A	y	Ay	Ay^2	Icg (element)
1	9.6	2.78	26.6	74.2	73.9
2	28.8	43.3	1 247.0	53 997.0	18 950.0
3	8.3	83.3	691.4	57 592.8	71.9
	46.7		1 965	111 664	19 095.8

$$\bar{y} = \frac{1965}{46.7} = 42.06''$$

$$Ixx = 19\,095.8 + 111\,664 - (1\,965 \times 42.06)$$

$$= 48\,074 \text{ in}^4$$

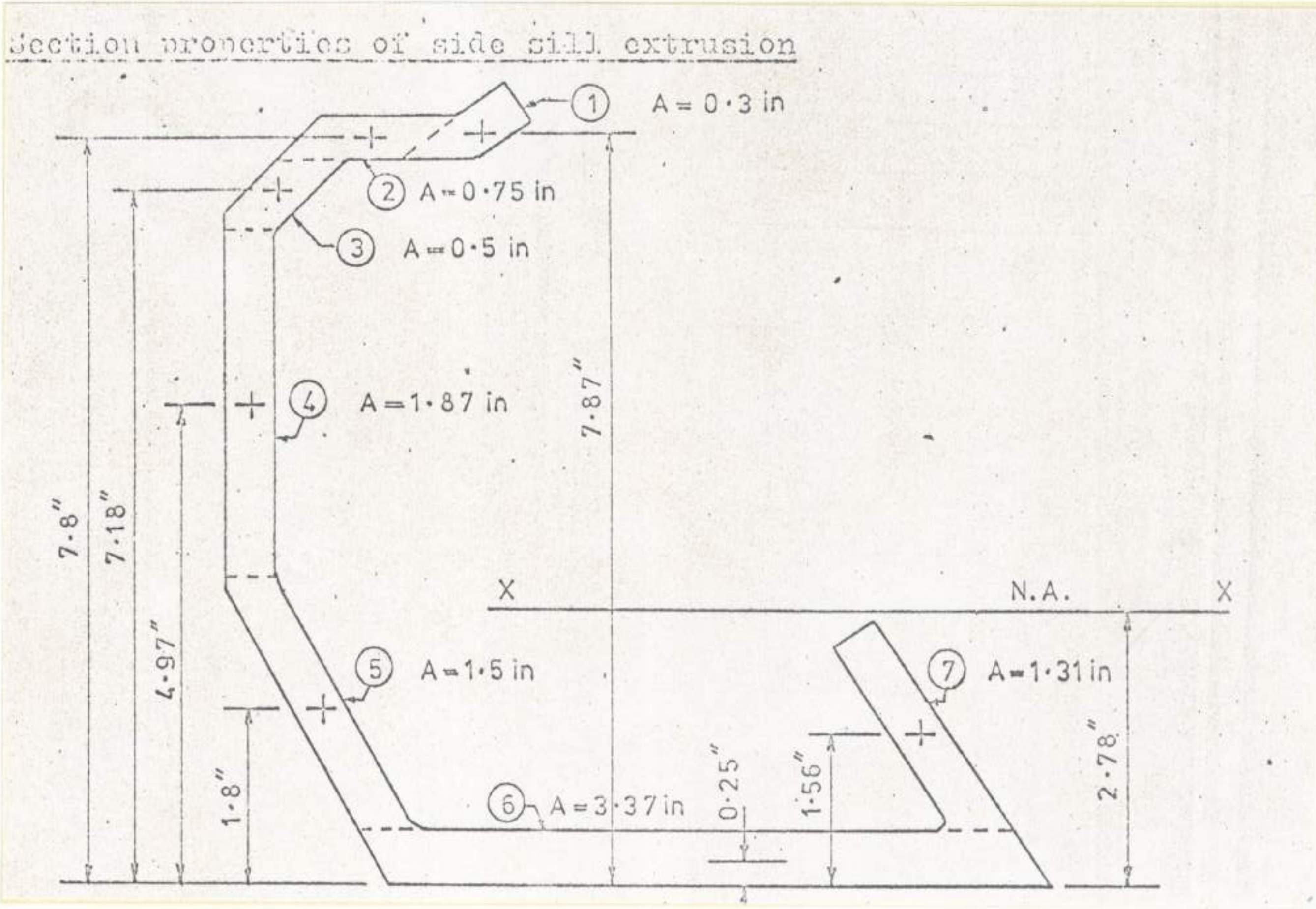


Fig. 19. Side sill extrusion

ELEMENT	A	y	Ay	Ay^2	Icg (element)
1	0.3	7.87	2.36	18.6	-
2	0.75	7.8	5.85	45.6	-
3	0.5	7.18	3.59	25.8	-
4	1.87	4.97	9.32	46.4	2.2
5	1.5	1.8	2.7	4.86	0.8
6	3.37	0.25	0.84	0.21	0.1
7	1.31	1.56	2.04	3.19	0.4
	9.6		26.7	144.66	3.5

$$\bar{y} = \frac{26.7}{9.6} = 2.78''$$

$$I_{xx} = 3.5 + 144.6 - (26.7 \times 2.78)$$

$$= 73.9 \text{ in}^4$$

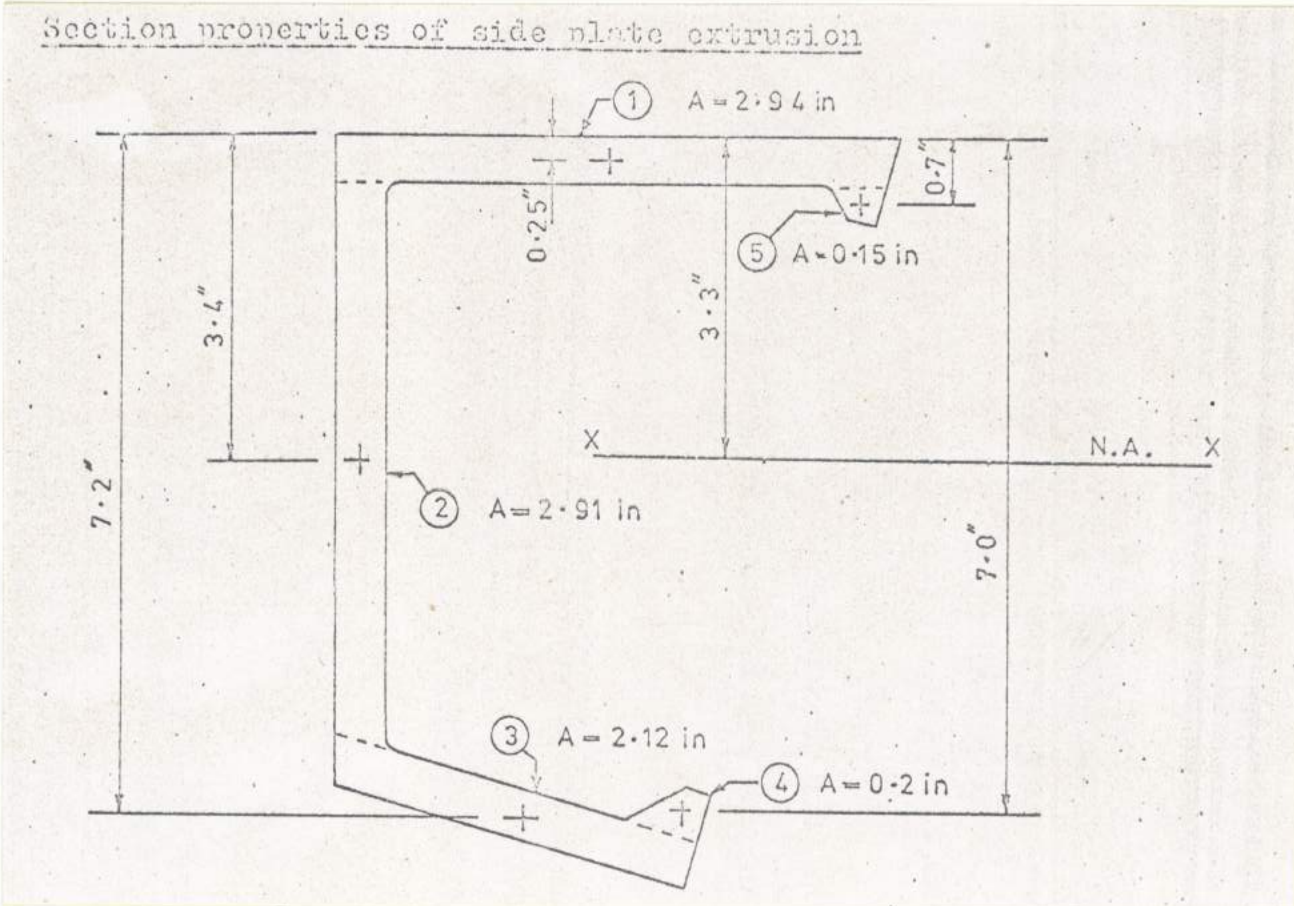


Fig. 20. Side plate extrusion

ELEMENT	A	y	Ay	Ay^2	Icg (element)
1	2.94	0.25	0.73	0.18	.06
2	2.91	3.4	9.89	33.64	8.2
3	2.12	7.2	15.26	109.9	0.4
4	0.2	7.0	1.4	9.8	-
5	0.15	0.7	0.1	0.07	-
	8.32		27.38	153.59	8.66

$$\bar{y} = \frac{27.38}{8.32} = 3.3''$$

$$I_{xx} = 8.66 + 153.59 - (27.38 \times 3.3)$$
$$= 71.9 \text{ in}^4$$

Effective top chord area

$$A_t = \frac{I}{y_t h} = \frac{48\,074}{41.24 \times 80.52}$$
$$= 14.48 \text{ in}^2$$

Effective bottom chord area

$$A_b = \frac{I}{y_b h} = \frac{48\,074}{39.28 \times 80.52}$$
$$= 15.2 \text{ in}^2$$

Flexural end load stresses at centre of wagon

The geometry of the effective chords and side walls is shown in Fig. 21.

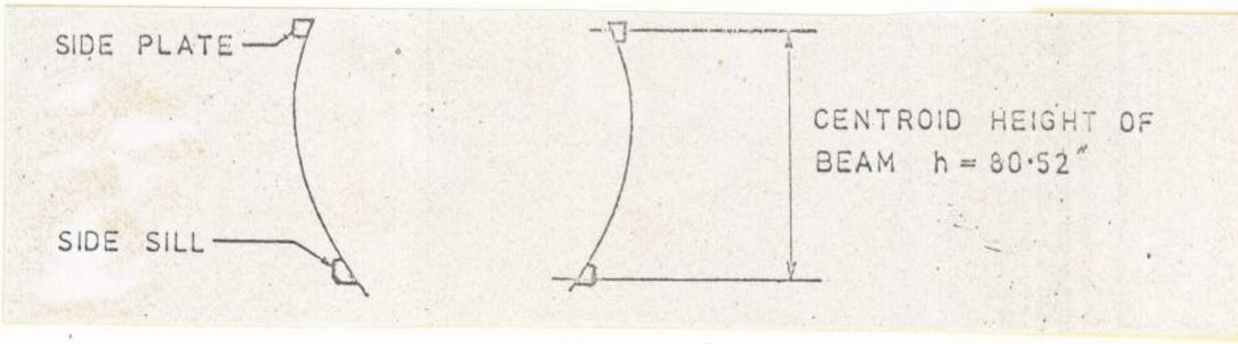


Fig. 21. Geometry of effective chords

The loads are shared equally by the two side walls.

The side plate and the side sill are assumed to form respectively the top and bottom chords of the beam. The side wall is assumed to carry the shear.

Static Stresses

From Fig. 15 the maximum bending moment at the centre of the wagon = 3 800 000 lbf.in. per side.

Effective area of top chord = 14.48 in^2

Effective area of bottom chord = 15.2 in^2

End load in top chord due to overall bending = $\frac{3\ 800\ 000}{80.52}$ = 47.200 lbf compressive

∴ Maximum stress in top chord due to overall bending = $\frac{47\ 200}{14.48}$ = 3 260 lbf/in^2 compression

End load in bottom chord = 47 200 lbf tensile

∴ Maximum stress in bottom chord due to overall bending = $\frac{47\ 200}{15.2}$ = 3 100 lbf/in^2 tension.

Dynamic stresses

From Fig. 15 the maximum bending moment at the centre of the wagon = 4 750 000 lbf in. per side.

End load in top chord due to overall bending = $\frac{4\ 750\ 000}{80.52}$ = 59 000 lbf compressive

∴ Maximum stress in top chord due to overall bending = $\frac{59\ 000}{14.48}$ = 4 100 lbf/in^2 compression

End load in bottom chord due to overall bending = 59 000 lbf tensile

∴ Maximum stress in bottom chord due to overall bending = $\frac{59\ 000}{15.2}$ = 3 880 lbf/in^2 tension

Shear web stability of side wall

The effective panel dimensions used in the design are shown in Fig. 22. The side panel length contained between the end wall and first diaphragm governs.

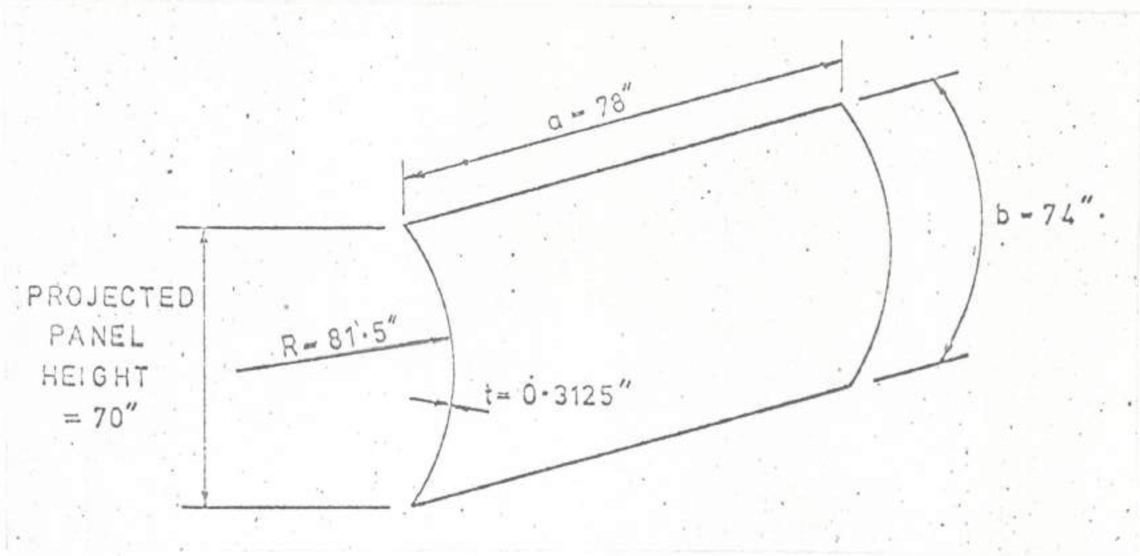


Fig. 22. Panel geometry

Panel data length a = 78"
width b = 74"
radius R = 81.5"
thickness t = 0.3125"

Since $\frac{a}{R} < 9 \quad (\frac{R}{t})^{\frac{1}{2}}$

The equivalent slenderness ratio

$$\lambda' = 2.8 \left\{ (\frac{R}{t})^3 \ \frac{a}{R} \ (\frac{t}{R})^{\frac{1}{2}} \right\}^{\frac{1}{4}}$$

$$= 2.8 \left\{ (\frac{81.5}{0.3125})^3 \ \frac{78}{81.5} \ (\frac{0.3125}{81.5})^{\frac{1}{2}} \right\}^{\frac{1}{4}}$$

$$= 90$$

The above λ' is for a complete tube of 81.5"R.
Allowing for limited panel width

$$\lambda = \frac{\lambda'}{\sqrt{1 + (\frac{t}{b} \qquad)^2}}$$

$$= \frac{90}{\sqrt{1 + (\frac{0.3125}{74} \times 90)^2}}$$

$$= 84$$

From the buckling diagram for 5083 - H321 alloy (Diagram 2)

$F_{cr\ shear}$ = 0.6 x 13 000 = 7 800 lbf/in^2

q_{cr} = 7 800 x 0.3125 = 2 440 lbf/in

The vertical reaction at the impacted end of the wagon from Fig. 17 is 202 260 lbf and is shared equally by the two side walls

∴ Average shear flow in each side wall

$q_{av} = \frac{202\ 260}{2 \times 70} = 1\ 440$ lbf/in

The critical shear flow is 2 440 lbf/in

Hence the reserve strength factor is

R.F. = $\frac{2\ 440}{1\ 440}$ = 1.7

Static shear stress in side wall of loaded wagon

The static vertical reaction at the end of the wagon is

V = 79 750 lbf from Fig. 14, which is shared equally by the two side walls

∴ Average shear flow in each side wall

$$q_{av} = \frac{79\ 750}{2 \times 70} = 570 \text{ lbf/in}$$

The critical shear flow is 2 440 lbf/in.

∴ Reserve strength factor under static conditions

$$R.F. = \frac{2\ 440}{570} = 4.2$$

Dynamic shear stress in side wall of loaded wagon

The static vertical reaction at the end of the wagon is

V = 99 700 lbf from Fig. 14 which is shared equally by the two side walls

∴ Average shear flow in each side wall

$$q_{av} = \frac{99\ 700}{2 \times 70} = 710 \text{ lbf/in.}$$

The reserve strength factor relative to the critical shear

$$R.F. = \frac{2\ 440}{710} = 3.4$$

Since the working shear flow is defined as ½ of the critical shear flow, a reserve strength factor R.F. greater than 2 with respect to the critical shear flow implies that the working stresses are not exceeded.

STUB SILL ANALYSIS

Properties of Centre Stub Sill

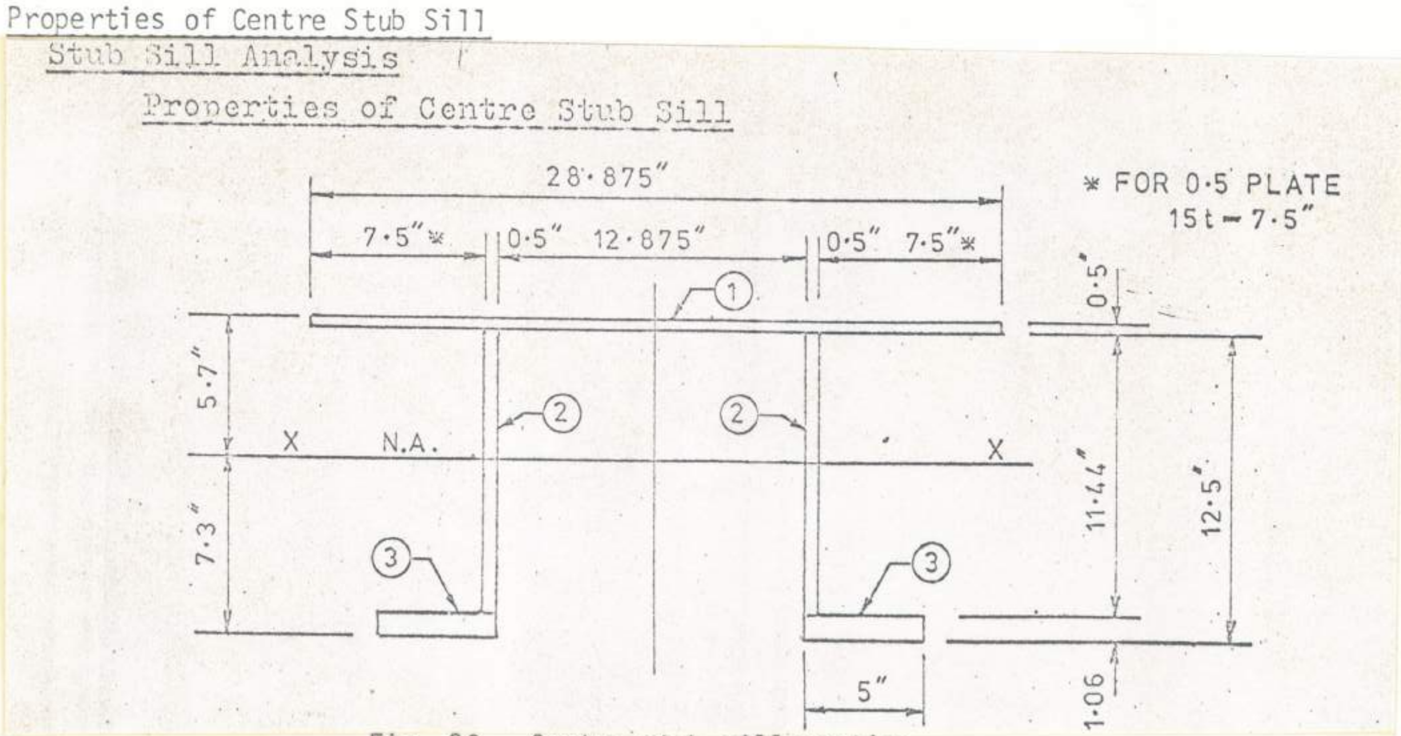


Fig. 23. Centre stub sill section

ELEMENT	b (total)	d	A	y	Ay	Ay^2	Icg (element)
1	28.88	0.5	14.44	12.75	183.6	2 340	3.0
2	1.0	11.44	11.44	6.78	77.6	525	125.0
3	10.0	1.06	10.6	0.53	5.6	3	1.0
			36.48		266.8	2 868	129.0

$$\bar{y} = \frac{266.8}{36.48} = 7.3''$$

$$I_{xx} = 129 + 2\ 868 - (266.8 \times 7.3)$$
$$= 1\ 049\ in^4$$

$$Z_{top} = \frac{1\ 049}{5.7} = 184\ in^3$$

$$Z_{bot} = \frac{1\ 049}{7.3} = 143.7\ in^3$$

IMPACT LOADING

High impact forces of 1 000 000 lbf, equivalent to two 80 ton wagons colliding at approximately 12 m.p.h., are usually encountered too infrequently to contribute to a significant amount of fatigue damage, provided the stresses created during impact have a positive margin of safety on the yield strength of the material. A reserve factor under this impact force in excess of 1, in relation to the yield of the condition of the aluminium alloy, is essential for good design.

The 1 000 000 lbf buffing load is applied to the stub sill through the rivets of the centre filler rear draft stop casting, in a manner consistent with the rivet geometry, resulting in the distribution shown in Fig. 24.

The buffing load is considered partially reacted by a 110 000 lbf inertial load from the bogies at the bogie centre plate bearing surface 8.85" below the centre line of the coupler. The remaining 890 000 lbf is assumed to be transferred to the bodysides via the shear plate to the side walls, giving a uniform shear flow (neglecting shear lag) of $\frac{890\ 000}{116.5} = 7\ 640$ lbf/in.

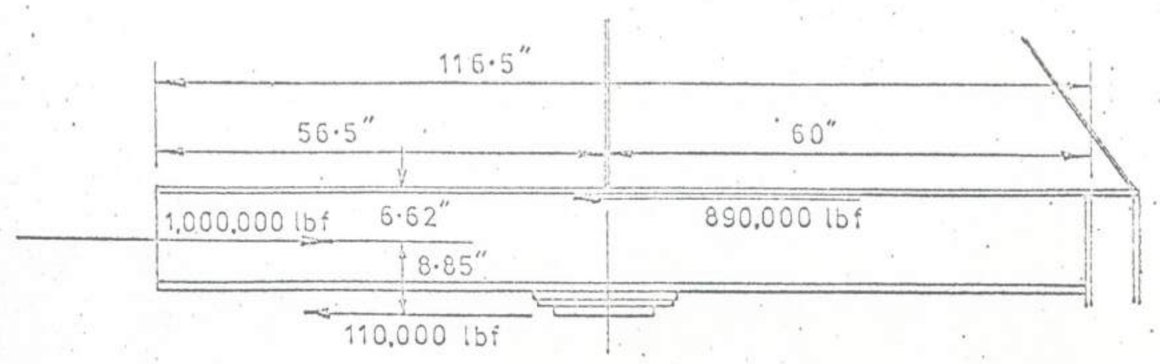


Fig. 24. Impact loading on stub sill

The load system shown in Fig. 24 gives rise to a couple

$$M = 1\ 000\ 000 \times 6.62 - 110\ 000\ (6.62 + 8.85)$$
$$= 6\ 620\ 000 - 1\ 701\ 700 = 4\ 918\ 300\ \text{lbf in.}$$

This couple is assumed to be reacted by the torsion box webs and main stiffeners in contact with the shear plate over a length of 69".

The forces reacting the couple are assumed to be uniformly distributed over a length of 23", being one third the length of the torsion box web and stiffener, at each end of the line of contact.

The distributed load at each end of line of contact =

$$P = \frac{M}{\frac{21}{3}} \times \frac{1}{\frac{1}{3}}$$

$$= \frac{4\ 918\ 300}{46 \times 23}$$

$$= 4\ 650\ \text{lbf/in.}$$

The stub sill system under impact loading is shown in Fig. 25.

Stresses in Stub Sill due to 1 000 000 lbf Impact Load are shown in Table 16.

TABLE 16. STUB SILL IMPACT LOAD STRESSES

Distance from headstock inches	Bending stress lbf/in^2		Direct stress lbf/in^2		Combined stress lbf/in^2	
	Top	Bottom	Top	Bottom	Top	Bottom
0	0	0	0	0	0	0
42.5 LH	+ 10 058	- 12 879	+ 8 900	same as top fibre	+ 18 958	- 3 979
42.5 RH	+ 12 203	- 15 626	- 2 859		+ 9 344	- 18 485
49.5 LH	+ 13 860	- 17 747	- 1 393		+ 12 467	- 19 140
49.5 RH	+ 10 939	- 14 008	+ 114		+ 11 053	- 13 894
56.5	+ 13 229	- 16 940	+ 1 580		+ 14 809	- 15 360
63.5 LH	+ 11 018	- 14 108	+ 3 046		+ 14 064	- 11 062
63.5 RH	+ 8 098	- 10 369	+ 4 554		+ 12 652	- 5 815
69.5 LH	+ 6 637	- 8 498	+ 5 810		+ 12 447	- 2 688
69.5 RH	+ 9 492	- 12 154	- 9 841		- 349	- 21 995
116.5	0	0	0	0	0	0

Note Tensile stress shown +ve, compressive shown -ve.

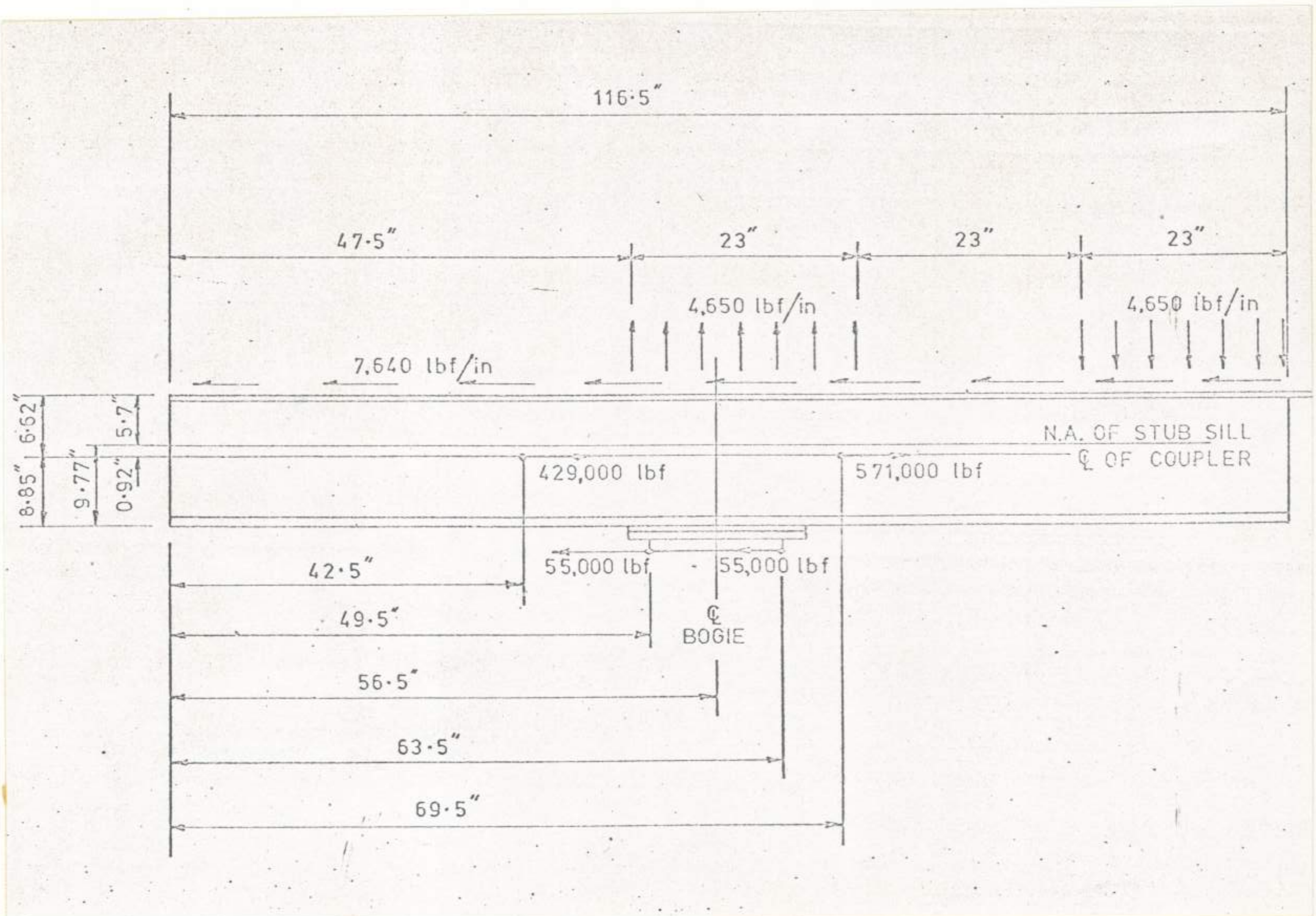


Fig. 25. Stub sill system under 1 000 000 lbf impact load.

Bending stress $= \frac{M}{Z}$ for top fibre $= \frac{M}{184}$

bottom fibre $= \frac{M}{143.7}$

Direct stress $= \frac{P}{A} = \frac{P}{36.48}$

Max. stress in top fibre = 18 958 lbf/in^2 tension

Max. stress in bottom fibre = 21 995 lbf/in^2 compression

The yield stress of the stub sill extrusion in 6061-T6 alloy.

F_{ty} = 35 000 lbf/in^2

The R.F. for top fibre $= \frac{35\ 000}{18\ 958} = 1.8$

R.F. for bottom fibre $= \frac{35\ 000}{21\ 995} = 1.6$

TORSION BOX ANALYSIS.

The end slope sheet, the end wall and the shear plate form a torsion box. The two internal ribs above the stub sill enable the torsion box to transfer the couple due to impact loading to the wagon sides, where it is reacted by the wagon weight and inertia forces. The value of this couple is 4 918 300 lbf in.

In addition to this couple, the torsion box receives a portion of the load applied by the lading to the end slope sheet as a result of impact. It is assumed that this load is 200 000 lbf for an impact load of 1 000 000 lbf.

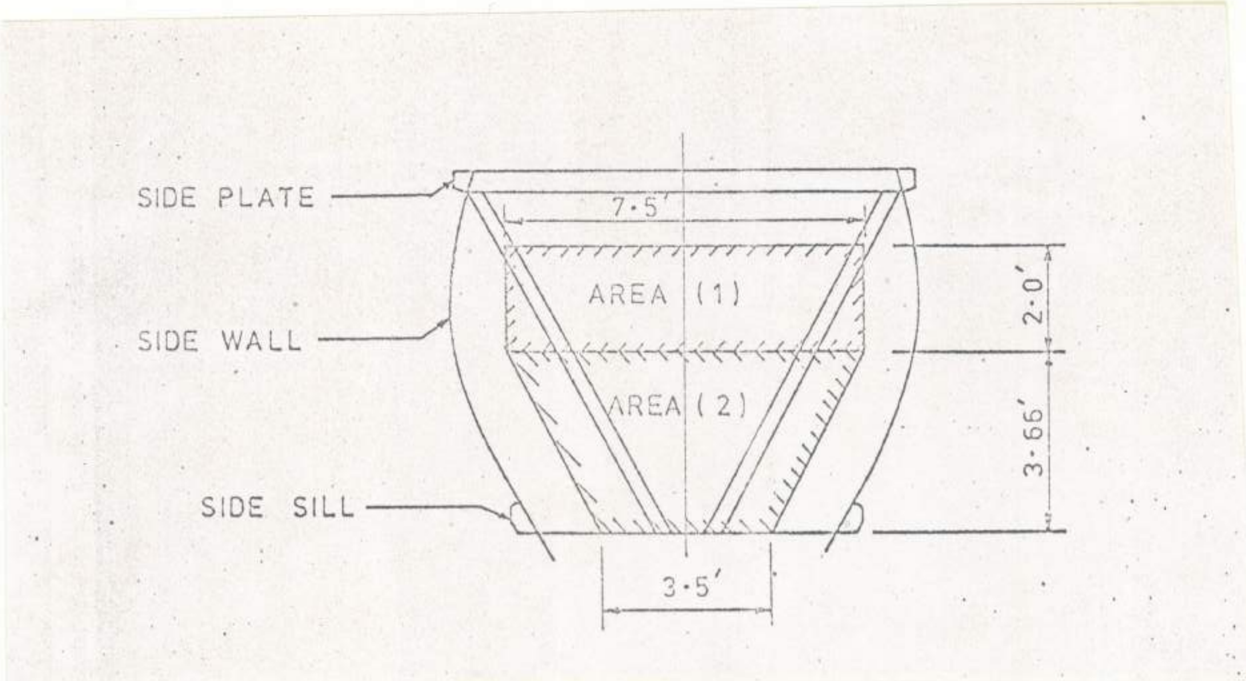


Fig. 26. Slope sheet under impact load

The approximate projected area of the end slope sheet above the shear plate $A = 60\ ft^2$

∴ Average pressure exerted on slope sheet by the lading

$P_{avg} = \frac{200\ 000}{60} = 3\ 333\ lbf/ft^2$

It is assumed that only that portion of the 200 000 lbf force acting on the shaded area of Fig. 26 tends to induce torsion in the torsion box

Area (1) = 2.0 x 7.5 = 15 $ft.^2$

Area (2) $= \frac{7.5 \times 3.5}{2} \times 3.66 = 20.1\ ft^2$

Shaded area = 35.1 ft^2

∴ Total load on shaded area = 35.1 x 3 333

= 117 000 lbf

∴ Horizontal shear at bottom of torsion ribs = 117 000 lbf

The centroid of the shaded area is 38" above the top of the shear plate.

Because they constitute a relief, the vertical down loads on the torsion box are neglected.

∴ The forces considered acting on the torsion box due to the load on the end slope sheet by the lading are shown in Fig. 27.

The additional torsional moment on the torsion box, due to this local effect of the lading,

M_a = 117 000 x 38 = 4 446 000 lbf in.

∴ The total torsional moment on torsion box = 4 918 300 + 4 446 000
= 9 364 300 lbf in.

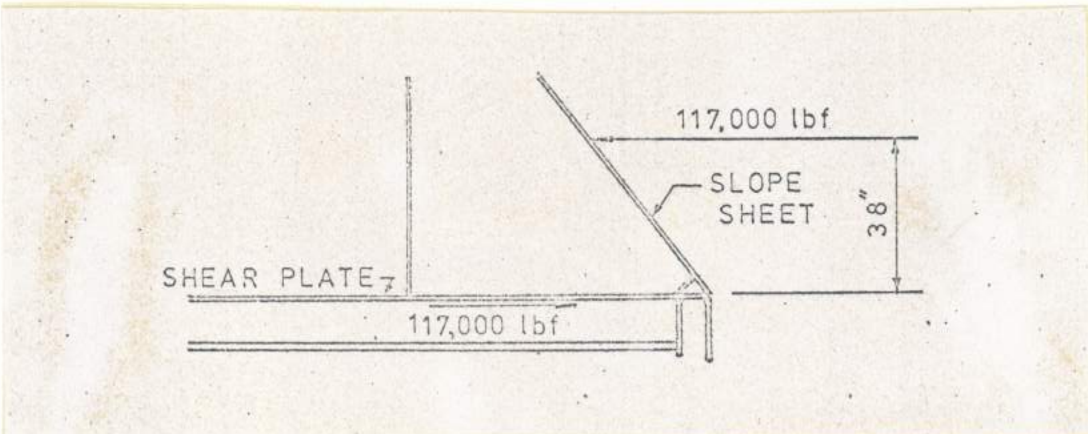


Fig. 27. Forces acting on torsion box due to lading.

The horizontal shear at the bottom of each rib

$= \frac{117\ 000}{2} = 58\ 500$ lbf.

∴ horizontal shear stress at bottom of each rib $f_s = \frac{58\ 500}{60 \times 0.3125}$
$= 3\ 120$ lbf/in^2

The torsional shear stress in the torsion box is calculated using the equation (*)

$$f_s = \frac{T}{2At}$$

where A = torsion box cross section enclosed area
t = wall thickness
T = applied torque

Enclosed area $A = \frac{79 \times 67.5}{2} = 2\ 670$ in^2

Slope sheet and end wall thickness t = 0.3125"
Shear plate thickness t = 0.5"

The total torsional moment is reacted equally by the two side walls, the applied torque

$T = \frac{9\ 364\ 300}{2} = 4\ 682\ 150$ lbf in/side

The end slope sheet and end wall being the same thickness will have the same average torsional shear stress

$$f_s = \frac{4\ 682\ 150}{2 \times 2\ 670 \times 0.3125} = 2\ 805 \text{ lbf/in}^2$$

and the average torsional shear stress in the shear plate

$$f_s = \frac{4\ 682\ 150}{2 \times 2\ 670 \times 0.5} = 1\ 753 \text{ lbf/in}^2$$

* Reference: Strength of Aluminium, by Aluminium Company of Canada Ltd, First, Second and Third Editions.

SHEAR PLATE ANALYSIS.

The 1 000 000 lbf buffing load is applied to the stub sill through the rear draft stop located in the shaded area on Fig. 29.

The buffing load is partially reacted by a 110 000 lbf inertial load from the bogies, acting through the bogie centre plate, and by a 117 000 lbf load, due to the lading bearing on the end slope sheet (refer torsion box analysis). The remaining 773 000 lbf is transferred by the shear plate to the side sills, as shown at Fig. 28.

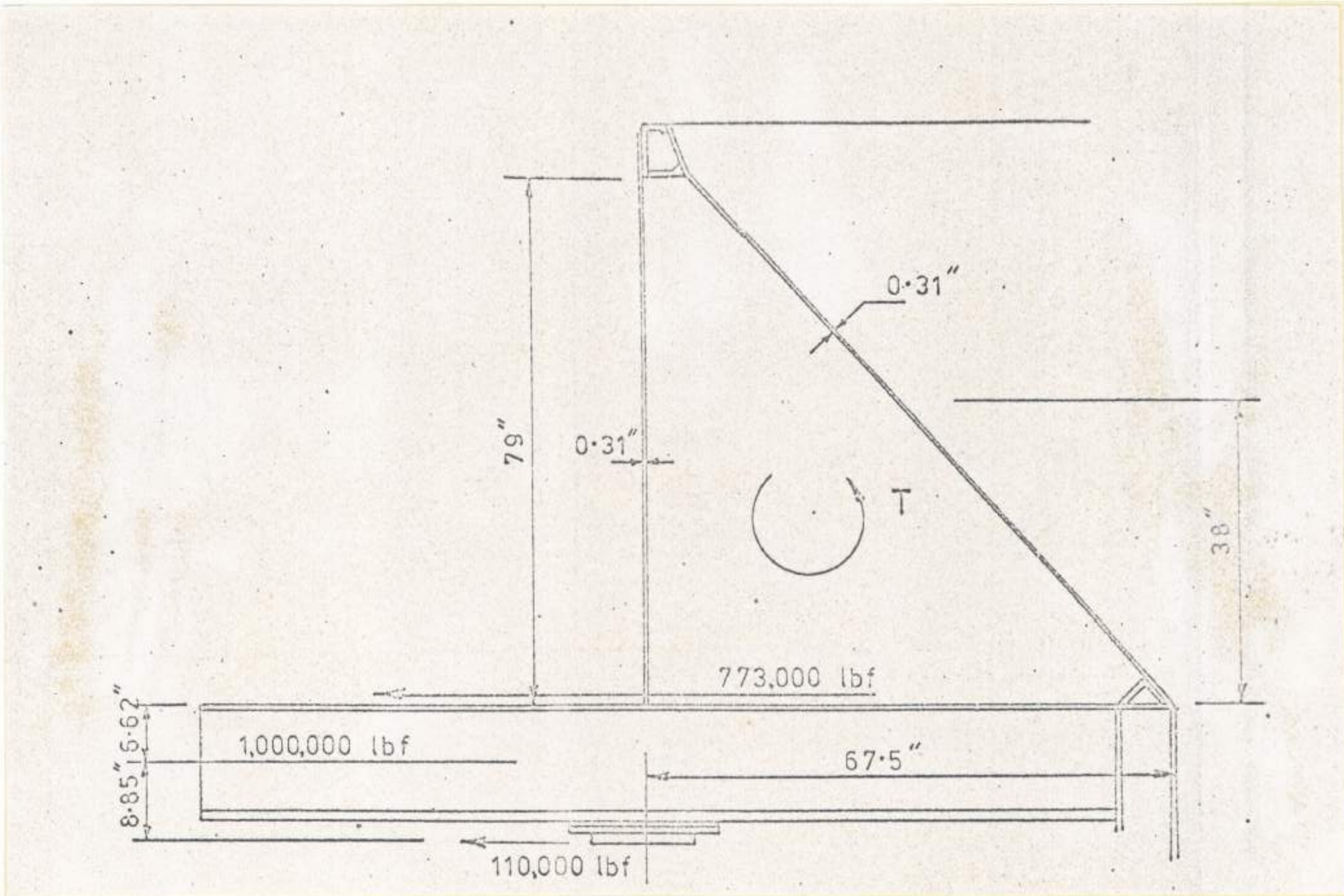


Fig. 28. Torsion box load and structure geometry.

The shear plate acts as a transverse horizontal beam spanning between the stub sill and side sills. The high load of 773 000 lbf to be transferred and the dimensional limitations of the shear plate make this beam critical in shear, hence the derivation of the name shear plate.

For the stub sill analysis it was assumed that the shear flow is uniform over the full length of the shear plate. However, for the shear plate analysis taking into account the relative stiffness of the members in region "A" and region "B", as shown on Fig. 29, and the high shear stresses created, it was assumed that, because of shear lag (*) only 1/3 of the 773 000 lbf. is considered to be transferred to the body sides by that portion of the shear plate between head-stocks and of bolster, shown on Fig. 29 as region "A". The remaining 2/3 of the 773 000 lbf is transferred by that portion of the shear plate within the torsion box, shown on Fig. 29 as region "B".

∴ Load transferred to bodysides by shear plate in region "A" $= \frac{773\ 000}{3}$

$= 257\ 666$ lbf.

Load per side $= \frac{257\ 666}{2} = 128\ 833$ lbf.

Resultant shear stress $f_s = \frac{128\ 833}{56.5 \times 0.5} = 4\ 560\ \text{lbf/in}^2$.

Load transferred to bodysides by shear plate in region "B" = 773 000 - 257 666 = 515 334 lbf

Load per side $= \frac{515\ 334}{2} = 257\ 667$ lbf

Resultant shear stress $f_s = \frac{257\ 667}{60 \times 0.5} = 8\ 590$ lbf/in2

* Reference: Stresses in Aircraft and Shell Structures, by Paul Kuhn. Chap. 4.

In region "B" the shear plate also acts as part of the torsion box and there is an additional torsional shear stress of 1 753 lbf/in^2, (refer torsion box analysis), which is additive.

∴ The maximum shear stress in the shear plate

$$f_s = 8\ 590 + 1\ 753 = 10\ 343\ lbf/in^2$$

The shear yield stress of the shear plate in alloy 5083 - H321, considering the welded condition, is

$$F_{sy} = 0.6 \times 18\ 000 = 10\ 800\ lbf/in^2$$

The maximum shear stress of 10 343 lbf/in^2 is just within the shear yield of the welded material and is considered acceptable as the 1 000 000 lbf impact load application is of small duration and infrequent. On the first such loading, if yielding was induced, the yield stress of the material would increase making a stronger structure.

It should be noted that, because of these high stresses created within the shear plate, particular care is required during design detail to ensure freedom from any inherent weakness and that fabrication conforms strictly to design requirements. All cut outs being finished free of nicks or grooves, welds only where specified and finished without crater cracks. Failure to observe the above in such a highly stressed structure in aluminium alloy, can only contribute to early failure.

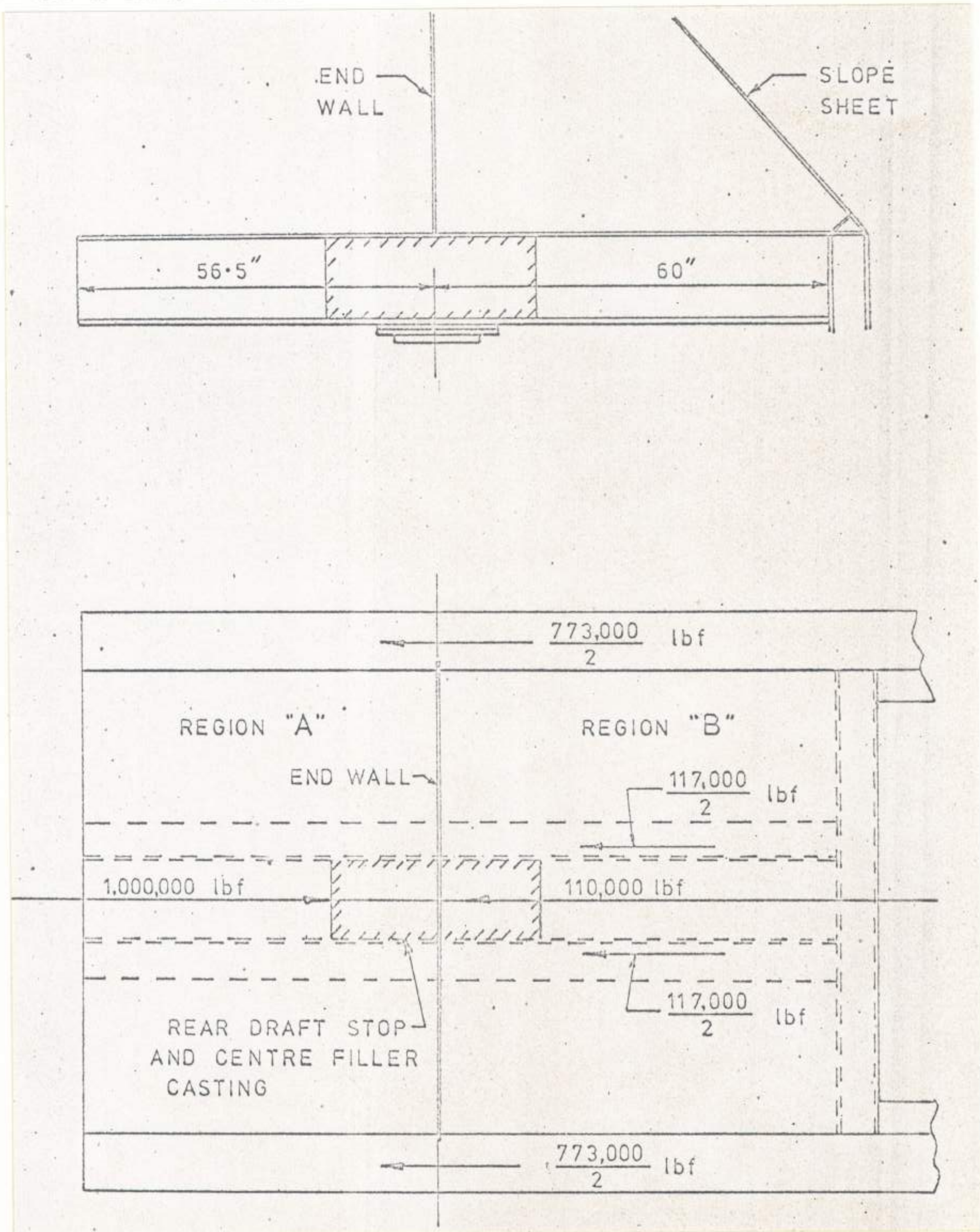


Fig. 29. Forces on shear plate.

Bottom Chord Under 1 000 000 lbf Impact Force

The maximum stresses in the side sills are due to the 1 000 000 lbf buffing force and occur at a point 66" in from each bogie, where provision is made in the wagon for the door end hinges.

The effective side sill end load section is composed of the side sill extrusion and a length of associated side wall sheet extending approximately 15 ft. above the top of the extrusion, as shown in Fig. 30.

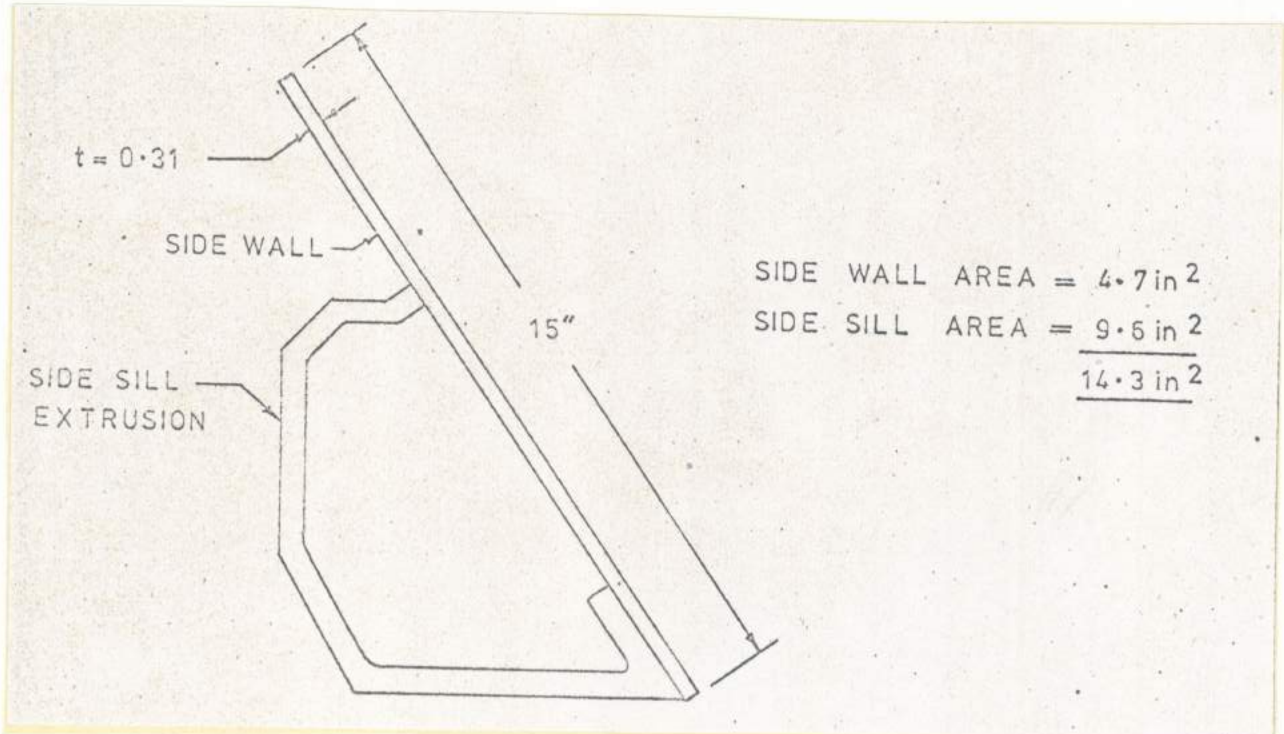


Fig. 30. Effective Side sill section

Extrusion alloy 6061 - T6

$F_{ty} = 35\ 000$ lbf/in^2

Side wall alloy 5083 - H321

$F_{ty} = 31\ 000$ lbf/in^2

The average yield stress of the side sill section considered

$$F_{ty\ av} = \frac{9.6 \times 35\ 000 + 4.7 \times 31\ 000}{14.3}$$

$$= 33\ 685 \text{ lbf/in}^2$$

The load transferred to bodysides = 773 000 lbf

$$\therefore \text{ load per side } P_{max} = \frac{773\ 000}{2} = 386\ 500 \text{ lbf}$$

The eccentricity of the application of this load in relation to the N.A. of the bodyside section, in Fig. 18, induces a bending moment on the bodyside.

$$M_e = 386\ 500 \times (42.06 + 6.625)$$

$$= 18\ 816\ 752 \text{ lbf in.}$$

End loads in top and bottom chord due to bending

$$P = \frac{18\ 816\ 752}{80.52}$$

$= 233\ 690$ lbf compressive load in bottom chord
tensile load in top chord

End stress in bottom chord due to bending created by end load

$$f_c = \frac{233\ 690}{15.2} = 15\ 374 \text{ lbf/in}^2 \text{ compression}$$

Compressive stress in bodyside due to direct end load

$$f_c = \frac{386\ 500}{46.7} = 8\ 276 \text{ lbf/in}^2 \text{ compression}$$

Stress in bottom chord due to weight of body and lading

f_t = 3 100 lbf/in^2 tension.

∴ Combined stress in bottom chord

f_c = - 15 374 - 8 276 + 3 100

= 20 550 lbf/in^2 compression

Since $F_{ty\ av}$ = 33 685 lbf/in^2

The reserve factor = $\frac{33\ 685}{20\ 550}$ = 1.6

Top Chord Under 1 000 000 lbf Impact Force

End load in top chord P = 233 690 lbf tensile

End stress in top chord due to bending created by end load

$f_t = \frac{233\ 690}{14\ 48}$ = 16 138 lbf/in^2 tension

Compressive stress in body side due to direct end load

$f_c = \frac{386\ 500}{46.7}$ = 8 276 lbf/in^2 compression

Stresses in top chord due to weight of body and lading

f_c = 3 260 lbf/in^2 compression

∴ Combined stresses in top chord

f_t = 16 138 - 8 276 - 3 260

= 4 602 lbf/in^2 tension.

END WALL ANALYSIS

Static Loading

The maximum static reaction at the bogie centre plate of 79 750 lbf is transferred directly through the stub sill webs to the end wall and thence to the car sides by the main end wall stiffeners as shown in Fig. 31.

The stress on section A-A

$$f_c = \frac{P}{2A \cos 27\tfrac{1}{2}^o}$$

$$= \frac{79\ 750}{2 \times 8.12 \times 0.887} = 5\ 530 \text{ lbf/in}^2 \text{ compression}$$

Dynamic Loading.

Under dynamic conditions the static loading stress will be increased by 25% giving

f_c = 1.25 x 5 530

= 6 912 lbf/in^2

The dynamic augment of 1 382 lbf/in^2 is within the fatigue strength for a transverse fillet weld of 2 000 lbf/in^2 for point of attachment of stiffener to shear plate, and longitudinal fillet weld of 3 000 lbf/in^2 for attachment of stiffener to end weld.

The average critical buckling stresses, in alloy 5083-H321 for each section Fig. 31 (*) are :-

Main Stiffeners
Section A-A

b	t	b/t	m		F_{cr}	bt	P_{cr}
3.7	0.31	11.5	5.13	58	18 400	1.15	21 160
9.0	0.31	28.1	1.63	45	22 000	2.81	61 820
2.0	0.31	6.2	5.13	31	23 800	0.62	14 756
2.0	0.31	6.2	5.13	31	23 800	0.62	14 756
9.0	0.31	28.1	5.13	143	1 400	2.81	3 934
						8.01	116 426

* Reference: Strength of Aluminium, by Aluminium Company of Canada Ltd, First, Second and Third Editions.

$$F_{cr\ av} = \frac{116\ 426}{8.01} = 14\ 535\ lbf/in^2.$$

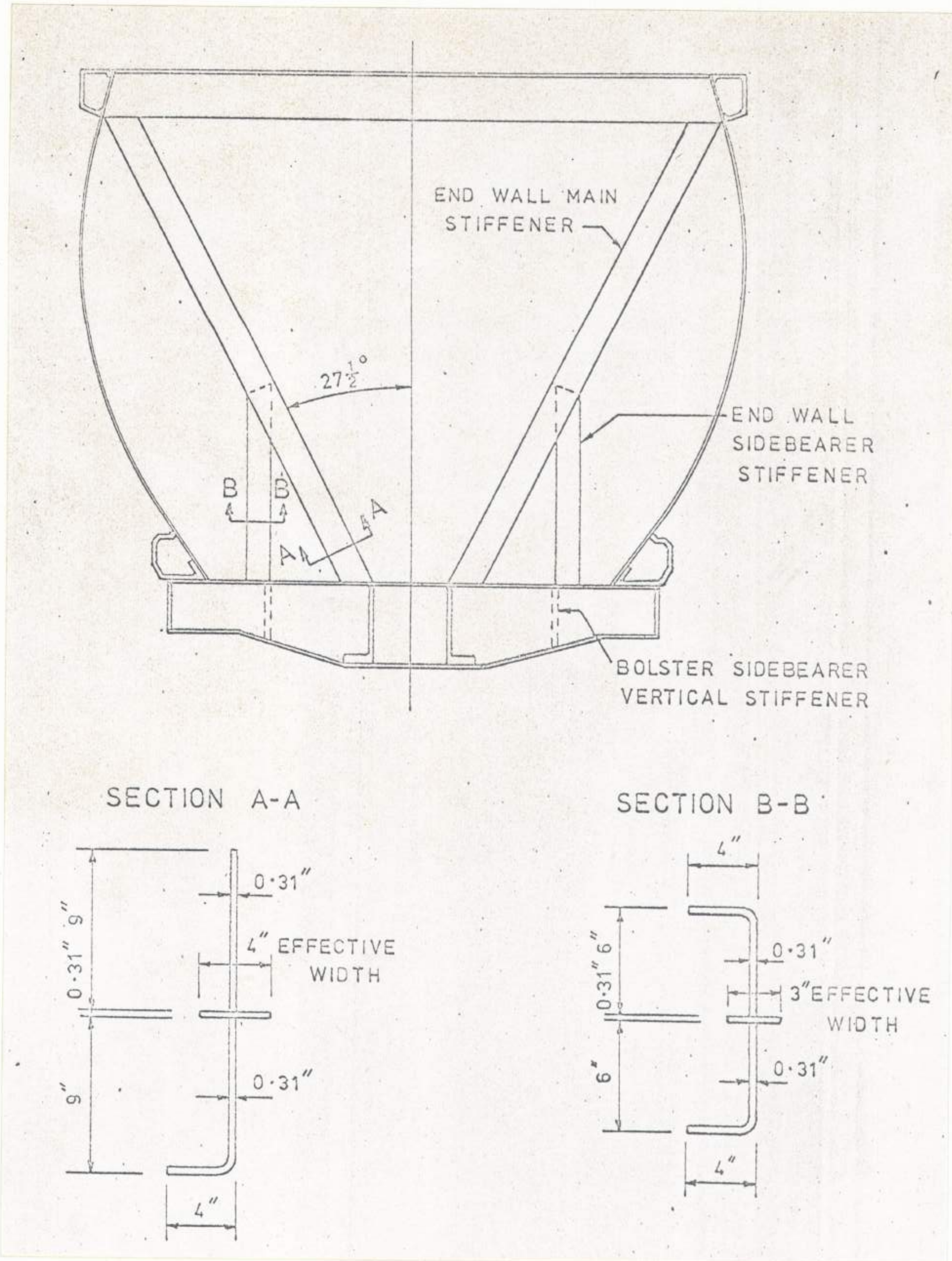


Fig. 31. End wall stiffeners

Side Bearer Stiffeners
Section B-B

b	t	b/t	m		F_{cr}	bt	P_{cr}
3.7	0.31	11.8	5.13	58	18 400	1.15	21 160
6.0	0.31	18.7	1.63	30	24 000	1.87	44 880
2.0	0.31	6.2	5.13	31	23 800	0.62	14 756
2.0	0.31	6.2	5.13	31	23 800	0.62	14 756
6.0	0.31	18.7	1.63	30	24 000	1.87	44 880
3.7	0.31	11.8	5.13	58	18 400	1.15	21 160
						7.28	161 592

$$F_{cr\ av} = \frac{161\ 592}{7.28} = 22\ 196\ lbf/in^2$$

IMPACT LOADING

The maximum vertical reaction on the bogie centre plate under buffing load of 1 000 000 lbf. is P = 202 260 lbf.

In addition, referring to the stub sill analysis, the application of the horizontal buffing load on the stub sill produces a load of 4 650 x 23 = 106 950 lbf. which acts down on the end wall stiffeners tending to relieve the stresses from the centre plate reaction. The simultaneous application of both loads would produce a minimum stress condition on section A-A. However, as the simultaneity of the two loads is doubtful, for design purposes the 202 260 lbf vertical reaction was combined with half of the relieving down load

$$f_c = \frac{202\ 260 - 53\ 475}{2 \times 8.01 \times \cos 27\tfrac{1}{2}^{\circ}}$$

$$= 10\ 470\ \text{lbf/in}^2$$

$$f_{cr}\ av = 14\ 535\ \text{lbf/in}^2$$

The reserve factor $= \frac{14\ 535}{10\ 470} = 1.4$

BODY SIDE BEARER LOAD.

The vertical load on the side bearer was assumed to be equivalent to the 79 750 lbf. static vertical load on the bogie centre plate. This load is transferred directly through the bolster side bearer stiffener into the end wall stiffeners.

$$f_c = \frac{79\ 750}{7.28} = 10\ 950\ \text{lbf/in}^2$$

$$F_{cr\ av} = 22\ 196\ \text{lbf/in}^2$$

The reserve factor under this loading which is considered would take into account dynamic conditions $= \frac{22\ 196}{10\ 950} = 2.0.$

Fatigue need not be considered because of the infrequency of occurrence.

STRESSES IN SIDE WALL DUE TO LADING

Assuming the lading exerts a hydrostatic pressure on the side wall, as shown in Fig. 32, and multiplying by 1.25 in order to allow for vertical accelerations.

Density of bauxite = 86 lb/ft.^{3}

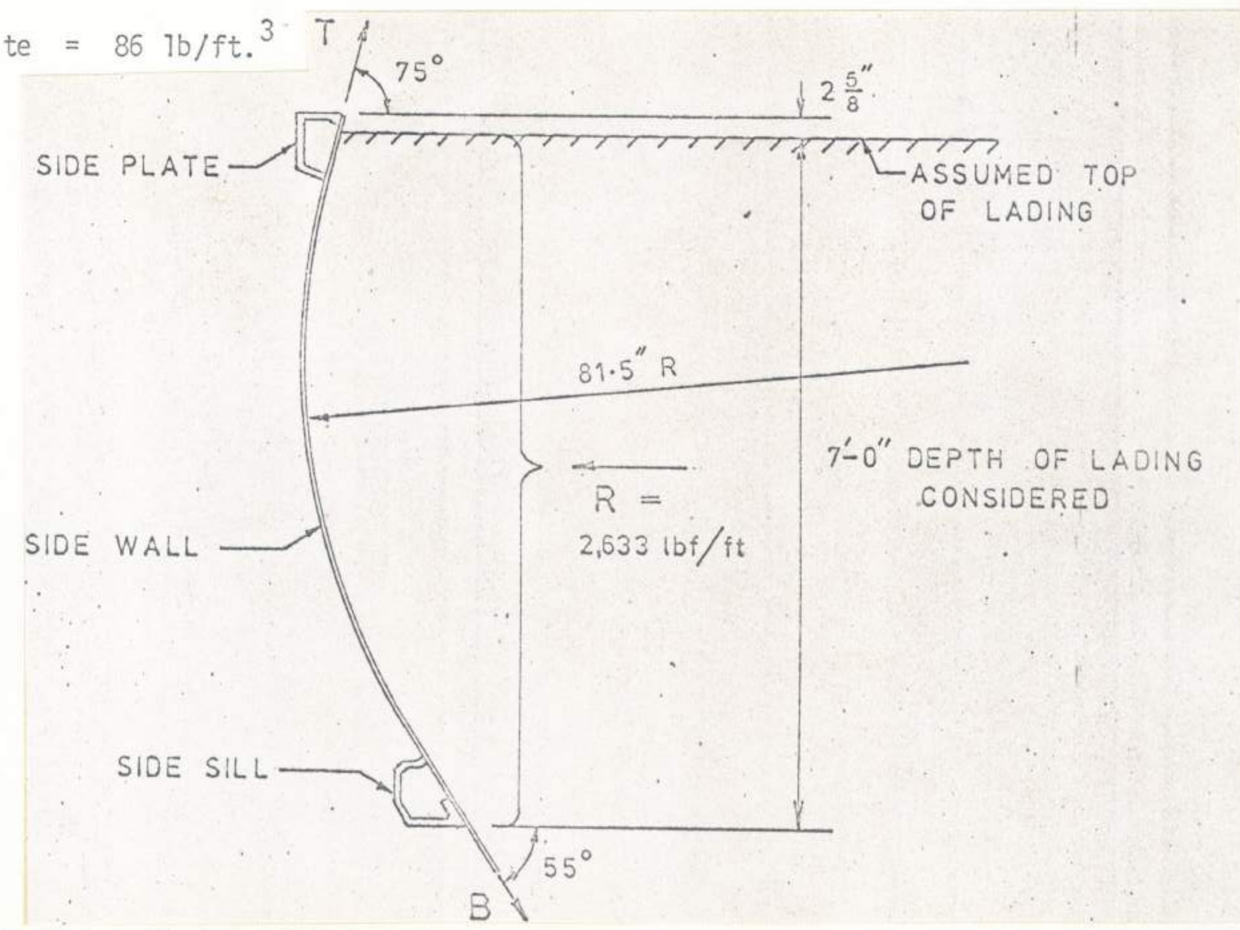


Fig. 32. Side wall lateral forces

Resultant $R = \frac{86 \times 7}{2} \times 7 \times 1.25 = 2\,633$ lbf/ft. run of side.

The tangential tension forces in the body side wall at the side plate and side sill are as shown in the polygon of forces at Fig. 32.

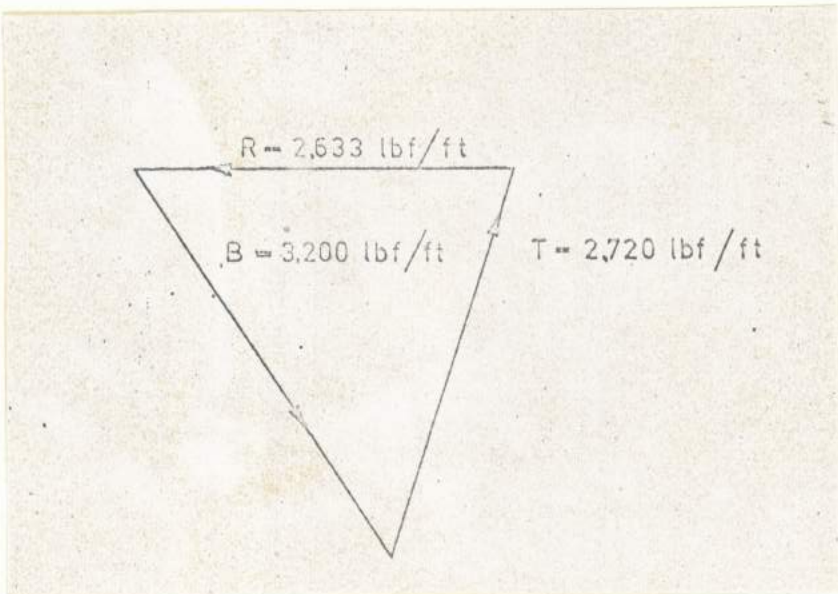


Fig. 33. Side wall polygon of forces.

The maximum tangential tension force B in the side wall occurs at the side sill connection and the resultant tension stress is

$$f_t = \frac{3200}{12 \times 0.3125} = 853 \text{ lbf/in}^2$$

The heat affected zone of the welded side wall creates a transverse welded condition, limiting the allowable working stress for 5083 - H321 alloy plate to 10 800 lbf/in^2. The calculated stress of 853 lbf/in^2 is well within the allowable stress.

The 2 720 lbf/ft tangential tension force T is resisted by the side plate extrusion and an effective width of side wall. The side plate extrusion is the same section as used for the composite wagon and the section properties of Fig. 34 about V-V will apply.

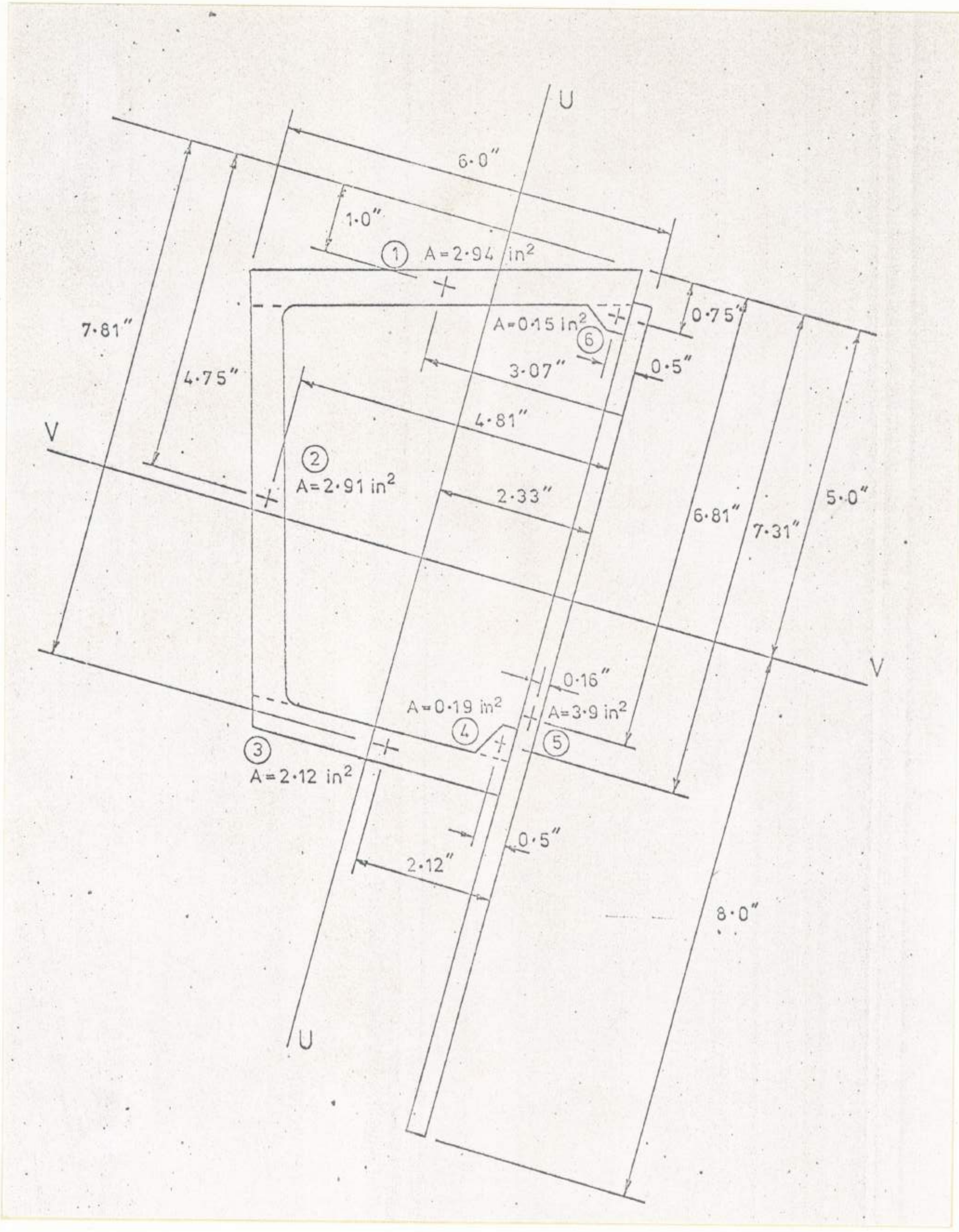


Fig. 34. Effective side plate section.

Summing moments about top corner edge of the extrusion shown in Fig. 34.

Section properties about V-V

ELEMENT	A	y	Ay	Ay^2	Icg (element)
1	2.94	1.00	2.9	2.9	0.55
2	2.91	4.75	13.8	65.6	7.68
3	2.12	7.81	16.5	129.3	-
4	0.19	7.31	1.3	10.1	-
5	3.90	6.81	26.5	180.8	50.86
6	0.15	0.75	0.1	0.1	-
	12.21		61.1	388.8	59.09

$$\bar{y} = \frac{61.1}{12.21} = 5.0 \text{ in.}$$

$$I_{vv} = Icg\ (\text{element}) + Ay^2 - Ay\bar{y}$$
$$= 59.09 + 388.8 - (61.1 \times 5)$$
$$= 142.39 \text{ in}^4$$

$$Z_{top} = \frac{142.39}{5} = 28.5 \text{ in}^3$$

Section properties about U-U

ELEMENT	A	y	Ay	Ay^2	Icg (element)
1	2.94	3.07	9.0	27.7	7.4
2	2.91	4.81	14.0	67.2	0.5
3	2.12	2.21	4.7	10.4	3.2
4	0.19	0.5	0.1	-	-
5	3.90	0.16	0.6	-	-
6	0.15	0.5	0.1	-	-
	12.21		28.5	105.3	11.1

$$\bar{y} = \frac{28.5}{12.21} = 2.33 \text{ in.}$$

$$I_{uu} = 11.1 + 105.3 - (28.5 \times 2.33)$$
$$= 50 \text{ in}^4$$

SIDE PLATE.

The side plate extrusion and side wall effective width forms, under the side wall tension, a beam on five supports as shown in Fig. 35.

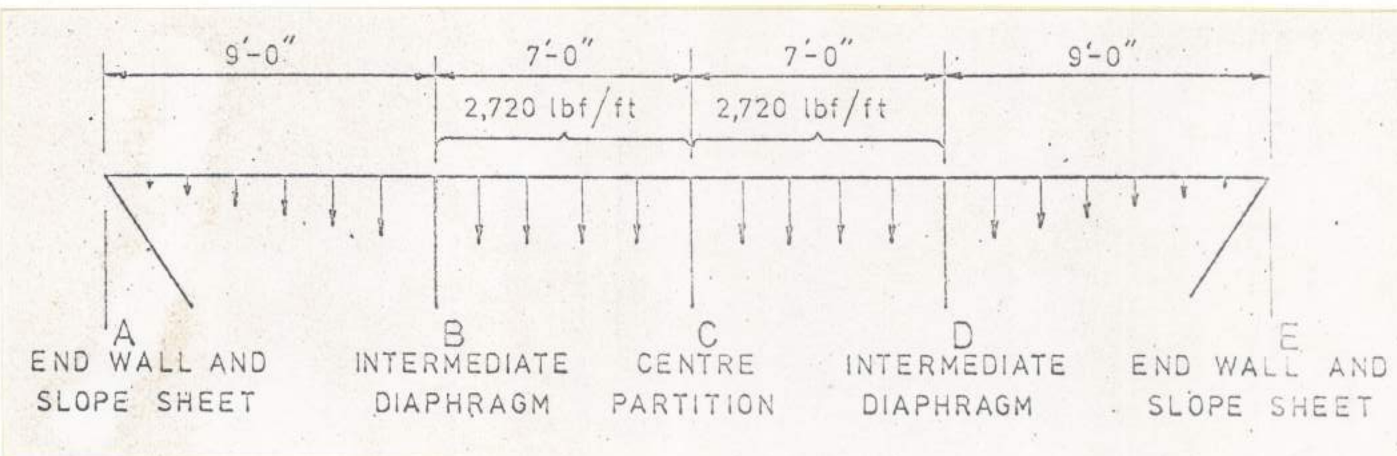


Fig. 35. Side plate loading

Since the end slope sheet reduces the depth of lading to zero at "A" and "E", spans A B and D E were considered to be loaded with a uniformly varying load from zero at "A" to 2 720 lbf/ft at "B". Spans B C and C D were considered to be uniformly loaded with 2 700 lbf/ft.

Assuming A B to be pinned at "A" and built in at "B" and assuming B C and C D to be built in at "B" "C" and "D" the following bending moments are obtained

For A B, the maximum bending moment occurs at $w = 2\ 720$ lbf/ft

"B" $= -\dfrac{wl^2}{15}$ (assuming a uniform varying load) $l = 9$ ft

$$= \frac{2\ 720 \times 9 \times 9 \times 12}{15} = -220\ 320 \text{ lbf in.}$$

For B C the maximum bending moment occurs at "B" and "C" $= -\frac{wl^2}{12}$ $w = 2\ 720$ lbf/ft, $l = 7$ ft.

$$= -\frac{2\ 720 \times 7 \times 7 \times 12}{12} = -133\ 280 \text{ lbf in}$$

$\therefore$ The maximum bending moment in the side plate section considered occurs in span A B at "B"
$= -220\ 320$ lbf in.

Using the section properties for the side plate effective section of Fig. 34 about V-V

$Z_{top} = 28.5 \text{ in}^3$

$f_{t\ top} = \frac{220\ 320}{28.5}$

$= 7\ 730 \text{ lbf/in}^2$ tension in the top face of the side plate extrusion.

The average yield stress of the effective side plate section is

$F_{ty\ av} = 31\ 486 \text{ lbf/in}^2$

The reserve strength factor R.F.

$= \frac{31\ 486}{7\ 730} = 4.$

Considering the peak stress occurring at the top edge, where the side wall and side plate extrusion are longitudinally welded, the weld yield strength at this point is 16 000 lbf/in^2 reducing the R.F. to $\frac{16\ 000}{7\ 730} = 2$, which is still adequately safe.

INTERMEDIATE DIAPHRAGM

The 2 720 lb/ft tangential pull of the side wall on the side plate between the end slope and centre partition is resisted by the intermediate diaphragm. An effective length of 8'-0" of side wall was considered to load one diaphragm member, resulting in the forces shown in Fig. 36.

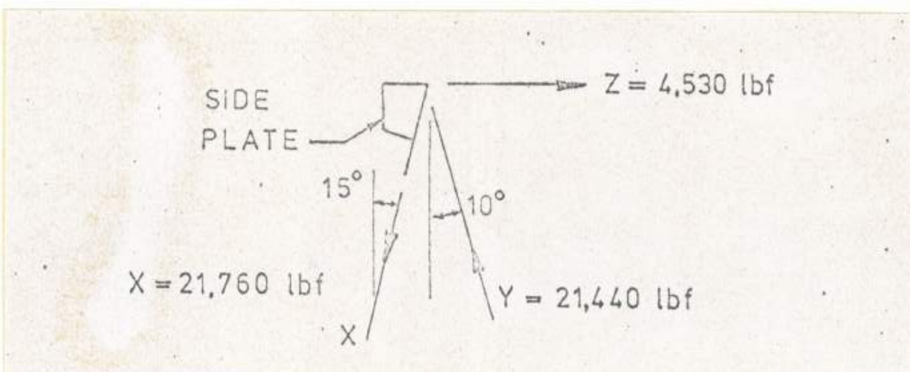


Fig. 36. Tangential forces due to lading

The inclined vertical load "Y" is resisted by a section of the diaphragm as shown in Fig. 37, which is assumed to act as an axially loaded pin connected strut.

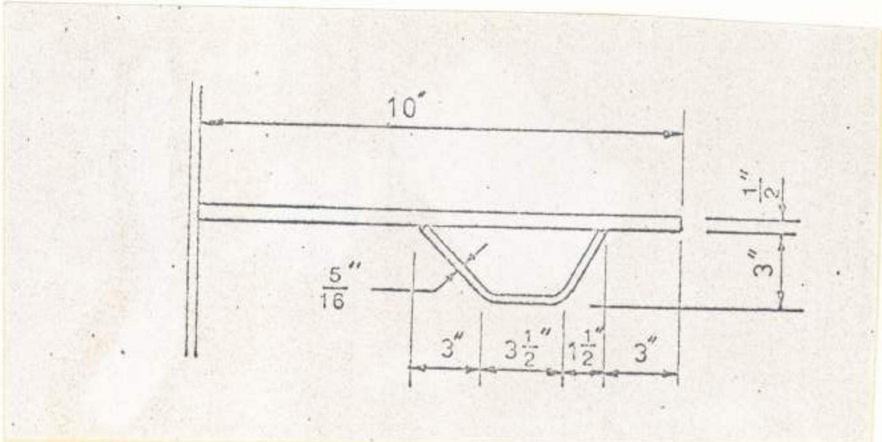


Fig. 37. Section through diaphragm side wall stiffener

Area = 8.0 in^2

I_{xx} = 11.49 in^4

r_{xx} = 1.2 in^2

L = 70"

∴ = 58

The critical buckling stress, from 5083 - H321 alloy buckling diagram,

$F_{cr} = 18\ 500\ lbf/in^2$

$f_c = \frac{21\ 440}{8.0} = 2\ 680\ lbf/in^2$

The horizontal transverse load "Z" is resisted by the section shown in Fig. 38.

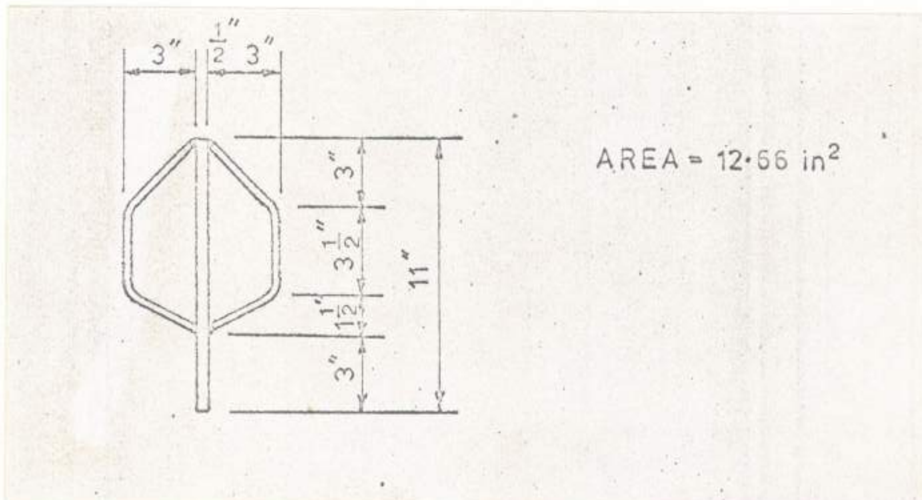


Fig. 38. Section through diaphragm horizontal component.

Load Z = 4 530 lbf

Assuming axial loading,

$f_t = \frac{4\ 530}{12.66} = 360\ lbf/in^2$

BODYSIDE UNDER COMBINATION OF LOADED WAGON CONDITION AND 300 000 lbf DRAWBAR PULL.

The critical stress location under the above combination of loads will, because of the minimum depth of bodyside combined with the change in section, occur at the door end hinge pockets i.e. 66" in from each bogie.

Vertical loads

The stresses in the top and bottom chords, at 66" in from each bogie centure, due to the overall bending moment of the laden wagon under dynamic conditions, shown in Fig. 15, are :-

Stress in top chord f_c = 480 lbf/in^2 compression

Stress in bottom chord f_t = 460 lbf/in^2 tension

Horizontal loads

The horizontal drawbar pull of 300 000 lbf is assumed to be equally divided into each body side giving a direct axial stress in each bodyside of

$$f_t = \frac{P}{A} = \frac{150\ 000}{46.7} = 3\ 210 \text{ lbf/in}^2 \text{ tension}$$

In addition to this direct axial stress, the vertical relationship between the centre line of the coupler and the neutral axis of the bodyside, creates an eccentric moment which was considered as follows.

From Figs. 18 and 25 the moment arm
= 6.62 + 42.06 = 48.68"

The bending moment in each bodyside due to this moment arm
= 150 000 x 48.68 = 7 302 000 lbf in.

Assuming this bending moment is shared equally by the top and bottom chords and the side walls carry only shear, ref. Fig. 21

End load in top and bottom chords $= \frac{7\ 302\ 000}{80.52} = 90\ 690$ lbf.

Bending stress in top chord $f_c = \frac{90\ 690}{14.48} = 6\ 260$ lbf/in^2 compression

Bending stress in bottom chord $f_t = \frac{90\ 690}{15.2} = 5\ 970$ lbf/in^2 tension

The combined stresses in the top and bottom chords, at a location 66" in from each bogie centre, due to the vertical and horizontal loads considered, are shown in Table 17.

TABLE 17

Stresses in lbf/in^2 due to		Top chord	Bottom chord
Body and lading weight (dynamic conditions considered)		480 c	460 t
Draw bar load	axial stress	3 210 t	3 210 t
	bending stress	6 260 c	5 970 t
Combined stress		3 530 c	9 640 t

These combined stresses are within the allowable stress of 17 500 lbf/in^2 for 6061 - T6 alloy. However as these stresses occur under dynamic conditions, fatigue needs to be considered.

The dynamic stress component of the 9 640 lbf/in^2 tension stress in the bottom chord of 90 + 3 210 + 5 970 = 9 270 lbf/in^2 is in excess of the fatigue strength limit of 8 000 lbf/in^2 for the as produced condition. The low incidence of this stress level in the life of a wagon is considered to be low enough for the 9 270 lbf/in^2 stress to be acceptable subject to the fitting of a design of gusset plate as shown in Photo 19.

The acceptance of this stress level with the fitting of gusset plates, was based on the experience of Alcan engineers in Canada, who, on their developmental work of a prototype all aluminium self supporting wagon, found from strain gauge tests that providing a suitable design of gusset plate was fitted in this area, the critical stresses could be reduced to within acceptable limits.

Bolster - Vertical loads

The prime function of the bolster in this wagon design is to transfer the vertical loads from the bogie centre plate, side bearers and jacking pads into the torsion box end wall and side walls.

The load path for each component was arranged to be continuous and direct, in the form of vertical webs or stiffeners provided between the bolster bottom plate and shear plate, under the bogie centre plates, side bearers and jacking pads. Bending stresses within the bottom bolster plate for these loads were thus theoretically eliminated.

CONSTRUCTION

Being an all welded structure, the success of the wagon construction depended on :-

(a) Establishment of weld procedures for all joint details

(b) Achieving and maintaining a high standard of welding

and (c) Joint detail alignment and fit up conforming to design requirements.

During the wagon development and design stage, each type of welded joint detail used was first proven before being applied to the design. To prove the joint details, samples of each type of welded joint was prepared and subjected to -

(a) a macro etch test to check for penetration and porosity of weld

(b) test to destruction to determine suitability of joint detail for the application.

Because of the size of the MIG welding handpiece, accessibility for welding of all welded joints had to be taken into consideration during design and assembly sequence, to ensure that no welds were required to be applied in locations difficult or impossible in practice for the MIG welding handpiece to operate in, to produce quality welds. Towards this end, a full size mock-up in wood was constructed of the end section, comprising of the torsion box, stub sill and bolster. This mock-up provided considerable assistance to both design and workshops staff, particularly in the torsion box area, when developing the final wagon detail, planning and construction stages.

Before commencing construction of the wagons, a welder training programme was again instituted, using the welders previously employed on aluminium alloy welding on the Class XB wagons, still employed with the department, as the nuclei.

Only those welders who had received adequate training and qualified in welding aluminium alloy were employed on the job and then to weld only the specific joints and positions for which they had qualified. To ensure that the welders were maintaining quality welds throughout the construction programme, each welder was required to weld test pieces at regular intervals and random "spot" tests, all which had to be carried out in the presence of a Shop Inspector.

Qualification was based on visual inspection, nick breaks, macro and bend tests.

In order to ensure that welding procedures laid down were strictly adhered to and weld quality was maintained, a welding supervisor was put in charge of the production welders employed on aluminium welding. The welding supervisor was also given the authority to direct defective weld areas to be removed and rewelded.

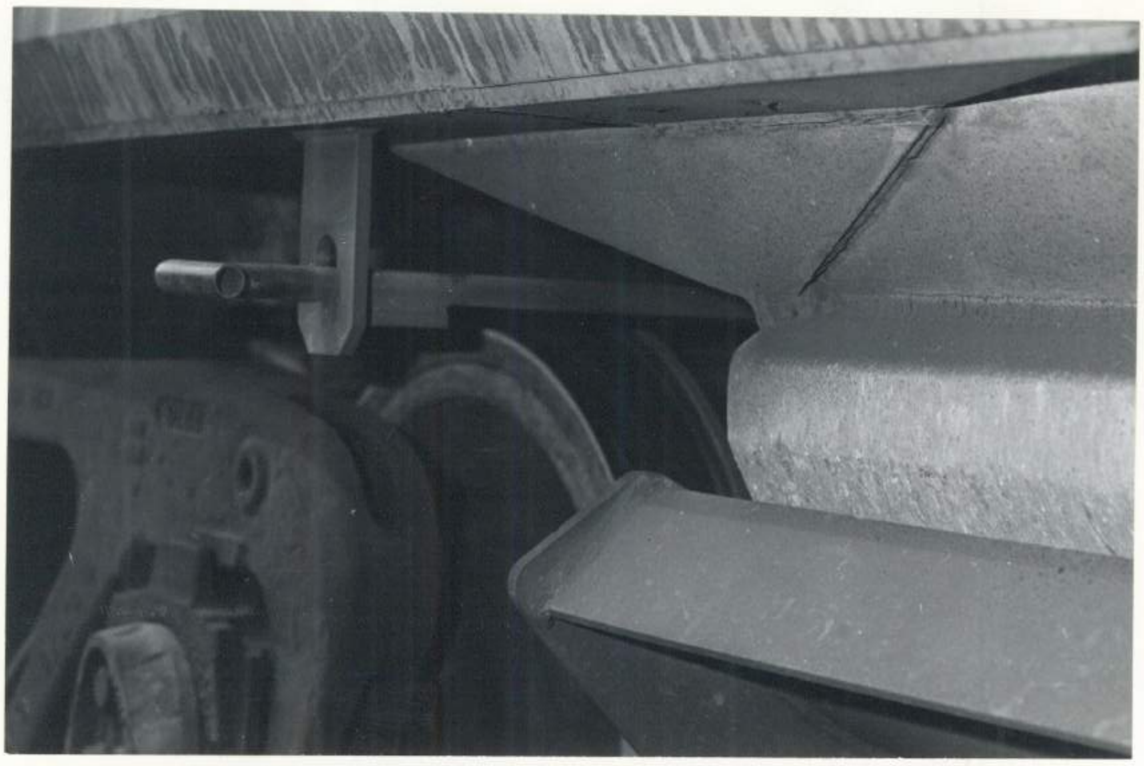


Photo 19. Addition of Gusset Plate.

Photo 20. Bottom discharge door jig.

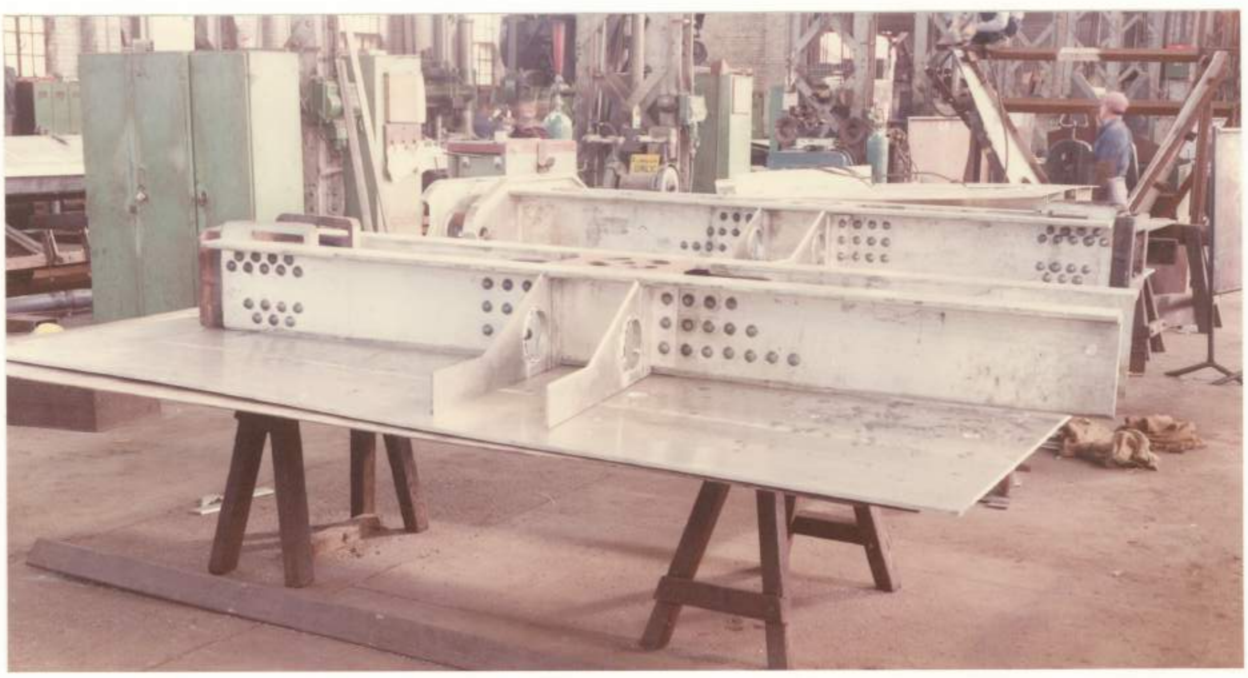


Photo 21. Stub sill and shear plate.

Equipment maintenance was also kept under surveillance to ensure that weld quality did not fall off duty to faulty machines.

Non-destructive tests, using X-rays for butt welds and dye penetration for fillet welds, were used to inspect the first wagon constructed. The results were used to show the welders any weld defects, thus assisting in further improving weld quality.

The geometry of the wagon is such that construction was divided into the following sub-assemblies, which were then brought together in a final assembly jig.

(a) Bottom discharge doors.
(b) End units comprising stub sills, bolster, shear plate end wall and torsion box ribs.
(c) Side walls.
(d) Centre partition.
(e) Intermediate diaphragms.

Where possible, throughout construction, downhand position welding was carried out for ease and speed of welding and quality of welds.

On the first fleet of 22 wagons constructed, all welding was carried out manually. However, as it became apparent that the fleet requirements would continue to increase, machine welding equipment was obtained and used on later wagon constructions. The use of which further improved weld quality and speed.

To minimise distortion, when welding aluminium alloys, it is essential that all plates and sections of an assembly be first securely clamped to a rigid base or jig, prior to welding. The welded assembly should then not be released until all welds have cooled sufficiently. This action is more important in aluminium alloy design than steel because of the greater contraction rate of aluminium welds.

DOORS - BOTTOM DISCHARGE.

Each door is comprised of two door sections, each fabricated from a formed top plate and two special extruded sections welded to the underside of the top plate to form a double box section, a central hinge and lifting point plate and two end hinge plates. To aid the longitudinal welding of the door extruded sections, a permanent backing strip was incorporated in the design of the extruded sections.

To maintain alignment of the door hinge bearings, a jig was constructed in which were mounted the central and end hinge plates. The fabricated door sections were then positioned in between and welded to the plates. Photo 20 shows this jig with an end and central hinge plate mounted in the jig, which was arranged so that the doors were built upside down to facilitate setting up and welding. A fabricated door section ready to be assembled and welded can be seen on trestles at the left of the jig. The outline of the prepared weld areas on the end and central hinge plates can also be seen.

STUB SILL ASSEMBLY INCLUDING SHEAR PLATE.

The striker casting and rear draft stop and centre filler casting were first assembled in between the two stub sill extrusions and riveted. To provide an optimum fit up between the stub sill webs and shear plate for welding, a light machining cut was taken along the top edge of each stub sill web and the castings in contact with the shear plate. A light machining cut was also taken across the underside face of the stub sill flanges and rear draft stop and centre filler casting, to obtain a true and flat contact surface for the bolster bottom plate.

This action was necessary to ensure that in this critical stressed area, the vertical loads had a direct load path from the bogie centre plate, through the stub sill webs into the torsion box end wall and stiffeners. Experience on another State Railway System in Australia had shown that failure could occur in this area if care of fit up was not taken to provide a correct load path.

A stub sill, striker casting and centre filler and rear draft stop casting assembly with bolster webs riveted on, prior to final positioning on the shear plate and welding, is shown in the upside down position in Photo 21. Behind this can be seen a completed welded assembly ready for turning over and fitting of the end wall, torsion box ribs and bolster bottom plate.

TORSION BOX

The torsion box ribs and end walls were fabricated and welded in the flat position before being assembled and welded to the top face of the shear plate. At this stage the bolster bottom plate and end hinge support members are welded into position. Final boring of the end hinge pin housings was then carried out on a horizontal boring machine, after which the end unit assembly is then ready for placing into position on the final assembly jig. Photo 22 shows a completed assembly prior to placing in the final assembly jig.

SIDE WALLS

The side wall plates were first cut to shape and the bottom radius preformed before welding the plates into a complete wall in the downhand flat position. The complete side wall plate was then mounted on a curved jig as shown in Photo 23, where the side plate, side sill and side wall bottom reinforcing extrusions are welded into position to the finished side wall contour, thus eliminating possible inbuilt stresses if welded with the side wall flat.

On later constructions it was found more practical for the side plate extrusion to be left off until the side wall was pulled into shape on the final assembly jig, thus allowing a better fit up of the side plate extrusion with both the side wall and shear plates.

CENTRE PARTITION.

The premachined steel casting incorporating the door operating pivot link bearings and the rough bored steel centre hinge pin housings were first bolted to each outer wall of the centre partition, using fitted stainless steel bolts. The sixteen 2.81" O.D. tubular aluminium alloy stays and side wall reinforcing plates were then placed in position and welded.

After completion of all welding, the centre partition assembly was sent to the machine shop for final boring to size of the door centre hinge pin housings.

INTERMEDIATE DIAPHRAGM

Welding of the stiffeners to the diaphragm plate was carried out in the downhand position. After welding, the side edges of the intermediate diaphragm assembly were finish contoured by bandsaw to match the side wall shape.

FINAL ASSEMBLY

Final assembly of the finished wagon was carried out in a jig designed to -

(a) maintain alignment of all door hinge points, both vertically and transversely.

(b) maintain alignment between the bearing surfaces of the bogie centre plates and side bearers.

Photo 22. Completed end unit assembly.

Photo 23. Side wall on jig ready for welding.

Photo 24. Completed body assembly.

The two torsion box shear plate and stub sill assemblies, two intermediate diaphragms and the centre partition were first positioned in the jig. The two side walls were then lifted into position, fixed at the bottom reinforcing extrusion, and, using chain blocks and special shaped hooks, were pulled into shape and welded. Photo 24 shows the wagon body after completion of pulling the sides to shape.

Typical of the above assembly sequence is depicted by Photos 25, 26 and 27, which show the assembly stages for the side wall of a recent design of covered hopper wagon constructed in aluminium alloy and designed specifically for haulage of alumina.

Photo 25 shows the end assemblies, diaphragms, roof section and hopper slope sheets placed in position on the main assembly jig, Photo 26 shows a side wall being lifted into position prior to pulling into shape and Photo 27 shows the side wall pulled into shape ready for welding and fitting of the side sill extrusions.

To allow double fillet welds to be used for the end wall and shear plate attachments to the side walls, the inside slope sheet of each torsion box was not positioned until all possible internal welding of the torsion box was completed. The end slope sheet, designed to be assembled in three sections was then fitted and welded from outside the torsion box in the hopper of the wagon. This method of assembly was also considered necessary from the safety aspect, as, should an operator welding inside a completely assembled torsion box be overcome by fumes, it would be almost impossible to manhandle him out due to the confined space.

CORROSION PREVENTION

The application of the steel striker casting and the steel centre filler and rear draft stop casting into the stub sill assembly is a critical area where the joint connections are subjected to and required to transmit the full buff and draw loadings, via a riveted joint, into the aluminium alloy stub sill webs.

To improve this connection, the coating of the steel interfaces was obtained by cadmium plating of all steel interfaces, to provide a thin uniform protective coating, resulting in a superior friction grip of the riveted joint.

Aluminium alloy interfaces were given

(a) A phosphoric acid - alcohol etch treatment
(b) A coating of zinc chromate primer.

Hot driven structural steel rivets were used to attach the steel castings to the aluminium alloy stub sills. After riveting, to prevent the ingress of moisture which could cause corrosion, the heads of the rivets in contact with the aluminium alloy were coated with a protective epoxy paint.

To seal against penetration of moisture between the joint surfaces, the joint edges between the steel castings and the aluminium alloy were liberally coated with a zinc chromate - koalin water repellent mastic.

All bolted steel to aluminium alloy connection contact surfaces were first liberally coated with a zinc chromate - koalin water repellent mastic before final assembly.

All bolts, studs, nuts and washers used throughout the wagon construction were in stainless steel. This departure from the previous use of cadmium plated bolts and nuts was brought about by the availability of stainless steel bolts, cold forged from stainless steel to AS G19 type 305, costing approx. only twice that of a similar structural quality steel bolt.

Studs and washers were in stainless steel type 321.

All aluminium surfaces were left unpainted except for stencilling requirements.

All exposed steel surfaces were finish painted silver to blend with the unpainted aluminium.

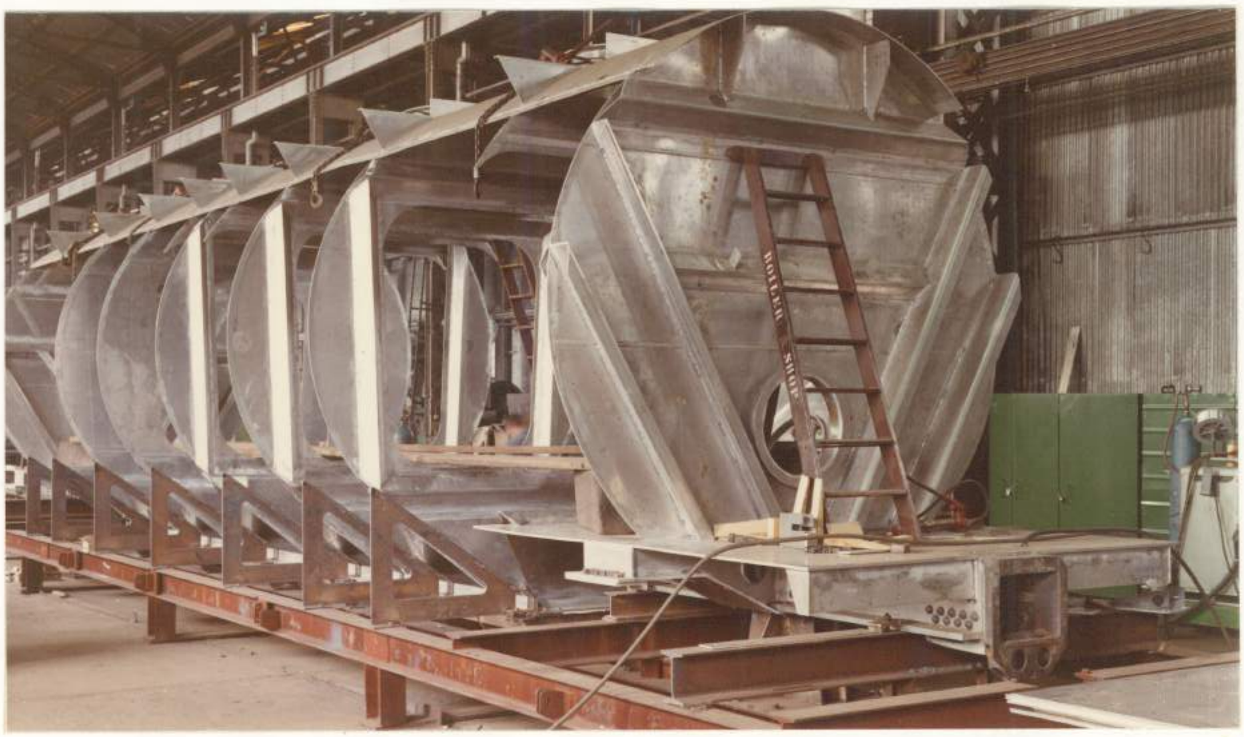


Photo 25. Sub assemblies placed in final assembly jig for fitting of side walls.

Photo 26. First side wall being lifted into position

Photo 27. Side walls pulled into position ready for finish welding.

MANUFACTURING AIDS

The combined knowledge and co-operation of Engineers and Tradesmen continually evolve improved techniques, some of which are listed below, saving many man-hours.

1. Band Saw

The cutting of large aluminium sheets and extrusions is easily accomplished on a Wood Mill Band Saw. The ingenious adaption of Lemcol bearings on stands at machine table height nullifies friction making heavy work easy and is most pronounced when scallop cuts are required in some designs to reduce otherwise "in line" welding stresses.

Subjected to an Industrial Dispute, the Arbitration Court in Western Australia ruled in favour of Wood Machinists performing this work. Wood Machinists treat aluminium as a hard hard-wood when tooling up. Photos 28 to 31 illustrate the set-up before and during the cutting of aluminium by Band Saw.

2. Senior Automatic Welding Manipulator (Better known to Journeymen as "Boom Welder")

Ostensibly for longitudinal welding, this machine is also used, in conjunction with other machines, for circumferential welding. Australian made, this machine was purchased from Methods Positioners Pty. Ltd., New South Wales in 1975. Photo 32 pictures the Boom Welder as installed.

3. Rotators

Known in Trade circles as Mechanised Rollers, they are obtained in sets of two and used extensively for rolling barrels in co-ordination with the "Boom Welder" for circumferential welding of tier to tier or tier to dished ends. This is now a most efficient process. Purchased from the makers Methods Positioners Pty. Ltd., New South Wales in 1974 they are shown in Photo 33 in conjunction with the "Boom Welder" in position.

4. Spring-loaded earth return

This shop-made spring-loaded device enables the complete welding of circumferential seams without stopping to reclamp the earth return cable. In addition to ensuring a free one-run weld around a barrel there is no twisting of the earth cable with consequent saving of wear and tear.

Photo 34 shows the device in position.

5. Automatic Welding Positioner

Photo 35 shows a variable position "manipulator" being used as an aid to preparing the edge of a flanged aluminium dished end for welding.

Purchased in 1974, this particular mechanised machine is produced in Australia by Methods Positioners Pty. Ltd., New South Wales. However, non-mechanised manipulators are easily manufactured and several shop-made units are in constant service.

6. Pneumatic Weld-Shaver (Better known to Tradesmen as a "Router")

Laborious hand cutting of particular edges of plates and sections in preparation for welding is cut to a minimum.

Photo 36 illustrates a Router in position.

Air-driven, these tools are manufactured by the Zephyr Manufacturing Co., California, U.S.A. Two were obtained in 1971.

7. Welding Techniques

Automatic and semi-automatic welding machines have practically usurped the former hand-held manual metal-arc stick electrode depositing methods in long aluminium welding runs.

The greater the knowledge gained by the designer on stress conditions, the greater are his demands on welding techniques, and whenever possible he designs for fully automatic processes. Understandably this is not always possible and the following machines are utilized in a modern Aluminium Fabrication Shop.

(i) Manual Metal Arc
Stick electrode depositing with hand held torch.

(ii) T.I.G. (Tungsten Inert Gas)
Fusion welding with non-consumable tungsten electrode, the welding area is protected by an inert argon or helium gas shield.

(iii) M.I.G. (Metal Inert Gas)
Continuous welding wire is fed from a coil; the molten metal is protected by a shielding gas. Processed by either fully-automatic or semi-automatic means and considering economies, Westrail Workshops use argon for ordinary superstructures and argon-helium (for deeper and consistent penetration) for Tanks proper, as the shielding gases.

8. Jigs and Fixtures

The extensive use of Jigs and Fixtures may be gauged from photographs, e.g. Photos 20, 23 and 25 to 27 inclusive.

Exact replicas are enabled to be produced for any new work and particularly for the replacement of components damaged in collisions or derailments.

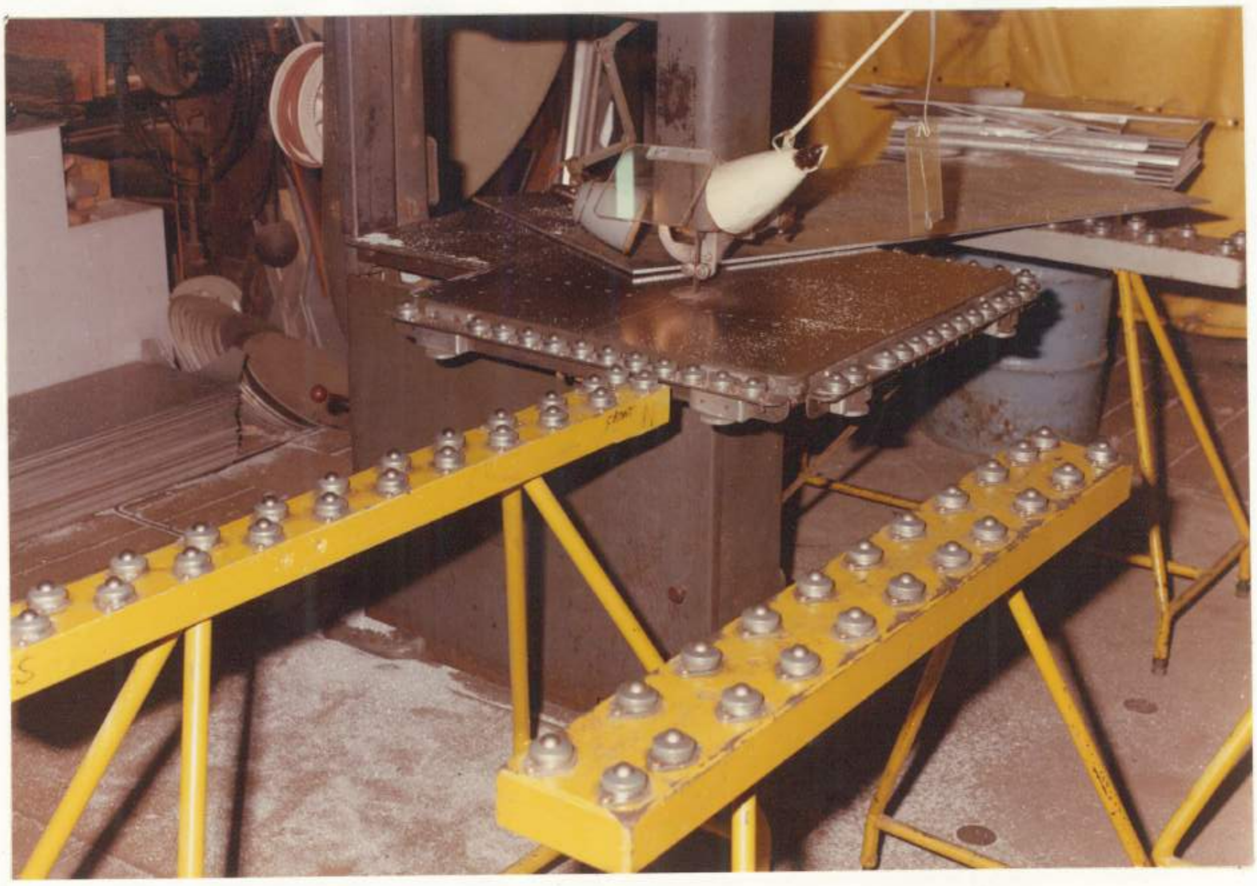


Photo 28. Arrangement showing Lemcol Bearings at Bandsaw Table and portable stands.

Photo 29. Close up of bearings at Bandsaw Table Top.

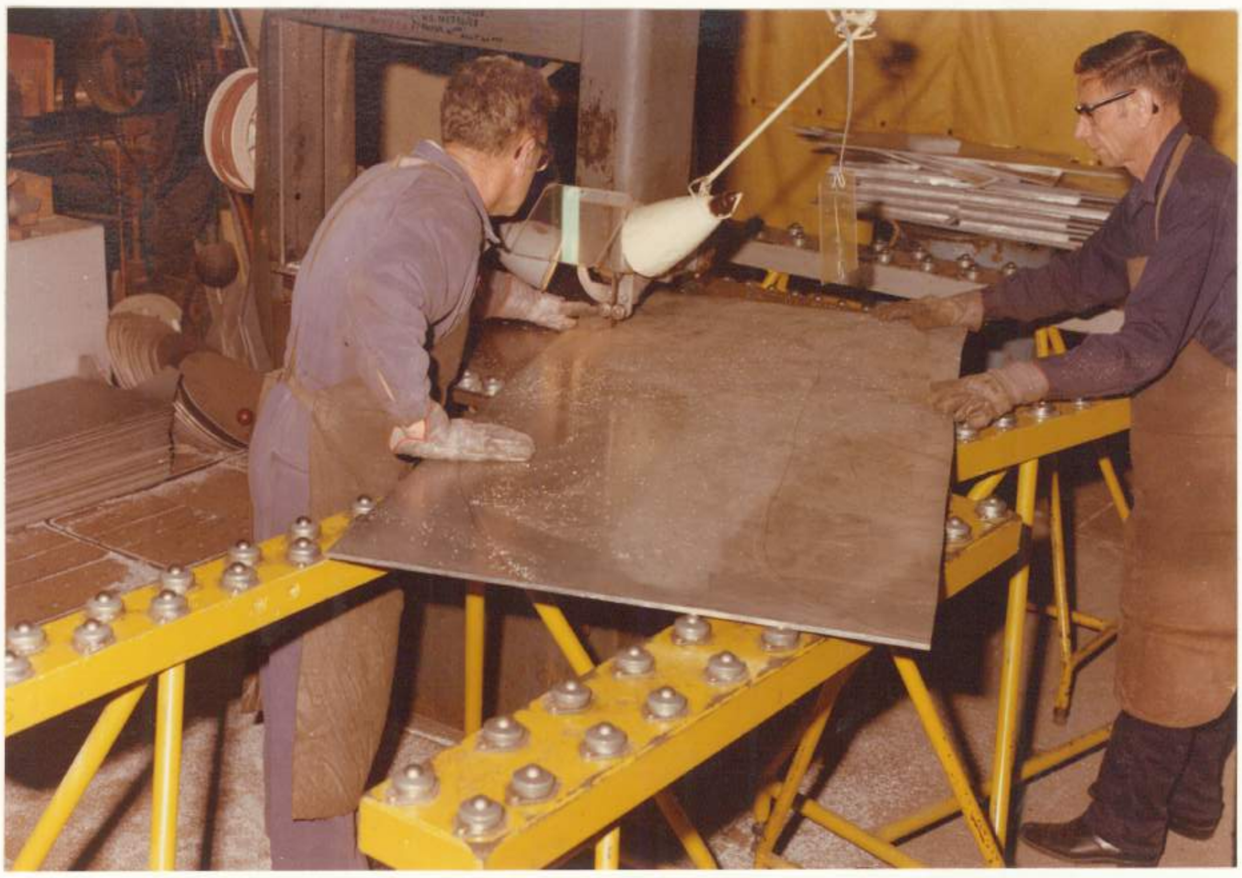


Photo 30. Commencing Bandsaw cutting of aluminium plate.

Photo 31. Bandsaw cutting of aluminium plate.

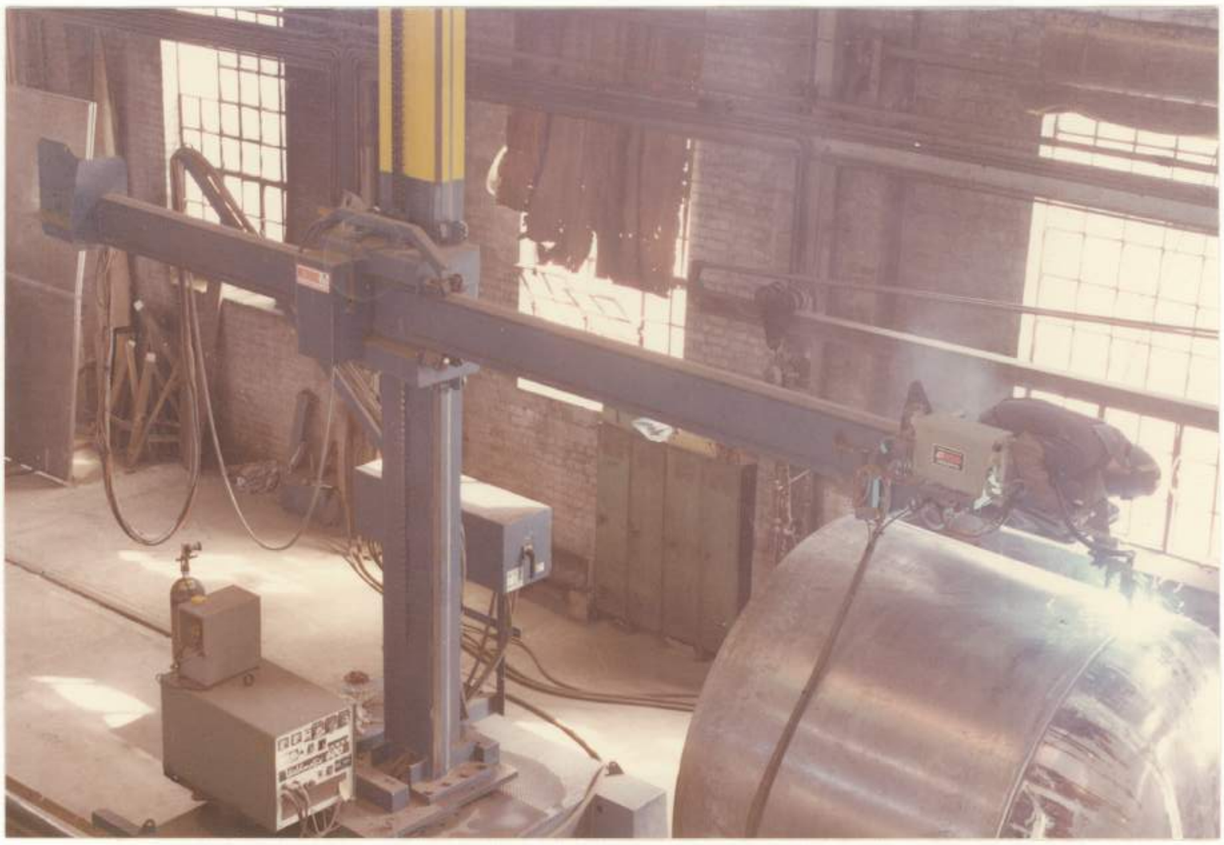


Photo 32. Senior Automatic Welding Manipulator (Boom Welder)

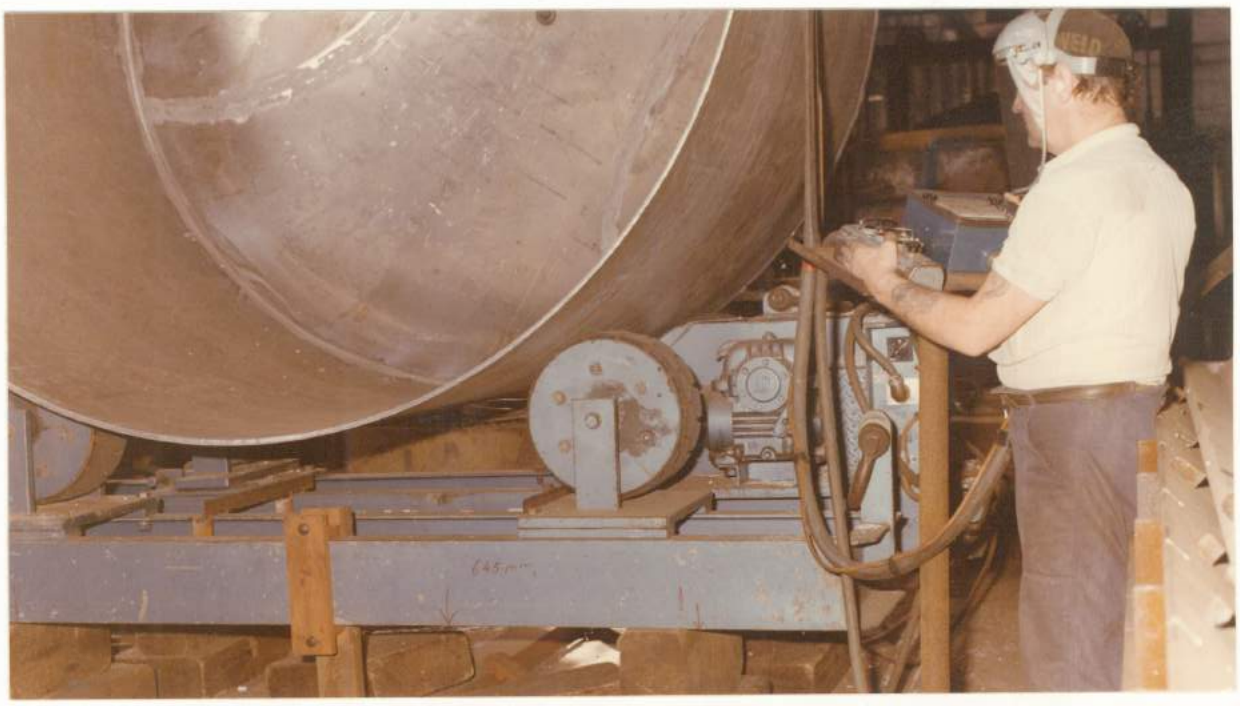


Photo 33. Rotators (Mechanised Rollers).

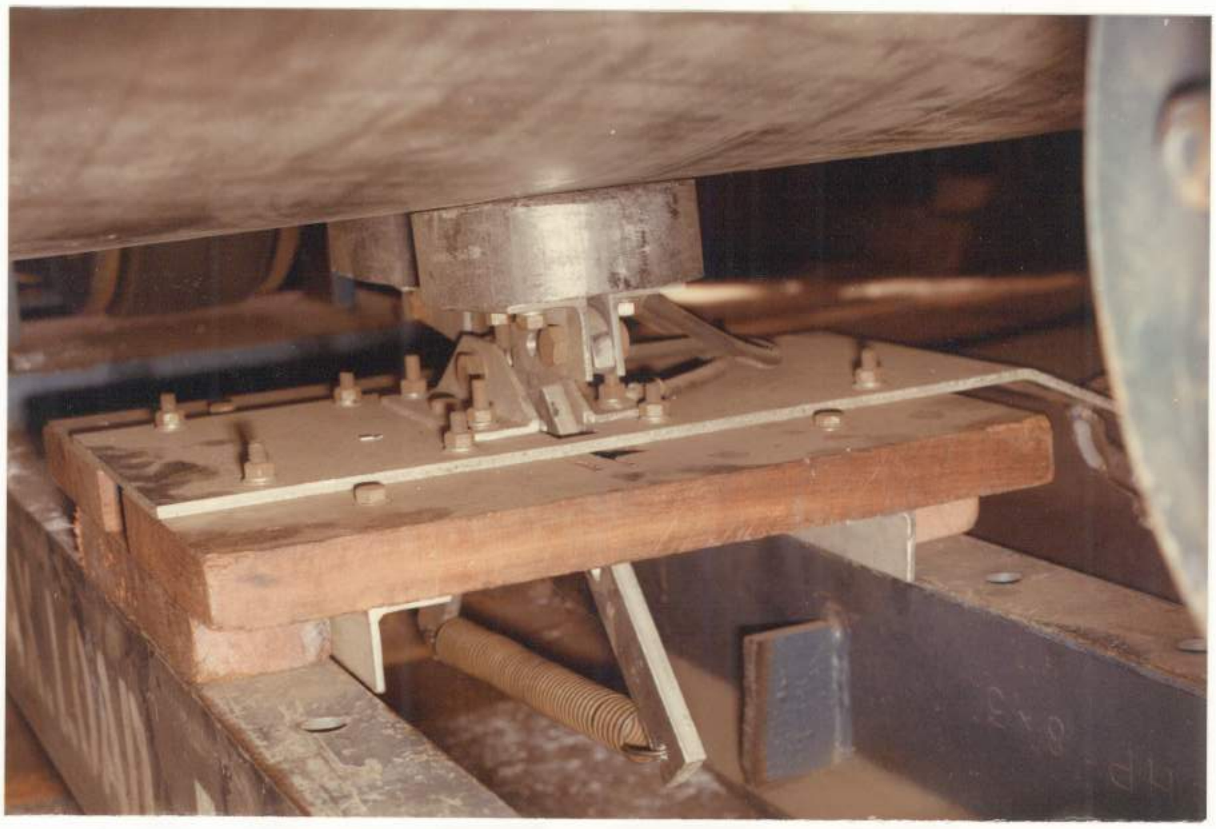


Photo 34. Spring Loaded Earth Return.

Photo 35. Automatic Welding Positioner.

Photo 36. Pneumatic Weld Shaver (Router).

PERTINENT POINTS.

1. Designs successful in aluminium are successful in steel, but not necessarily vice-versa.

2. When a railway wagon is made of aluminium in lieu of mild steel it loses weight, the loss of weight being approximately equal to the weight of aluminium, which is then converted to payload.

3. Although the cost differential of Aluminium to Steel ($1500 and $250 per tonne respectively), of six to one appears at first to be somewhat excessive the fact that aluminium, when designed to meet equivalent requirements, is about half the weight of steel whittles the cost differentiation down to three to one.

4. A lesser number of aluminium wagons are required to cover a transport task equal to that carried out by all-steel wagons.

5. Economic studies indicate that, under maximum utilisation conditions, the extra capital costs to construct an all aluminium wagon will be more than compensated by the incremental revenue from the increased payload.

6. Variations to standard extrusions are attractive feasibilities to designers. Quite often, individually ordered special extruded sections incorporate features covering several functions and provide economies in fabrication costs and assemblies. Costs of dies are frequently amortised when sufficient quantities are ordered making the design of special shapes much better practical and economic propositions.

7. At times, design calculations indicate that light componentry can withstand service requirements but have need to be increased to more robust dimensions to withstand shop-handling during manufacture and lifting in cases of derailments.

8. Successful D.C.F. (Discounted Cash Flow) exercises need to be individually submitted when justifying the purchase of new machines - a relatively easier task when combining these deals with aluminium production machines.
Four typical examples are included for the purchase of :-

Appendix F.	Automatic Welding Manipulator (Boom Welder).	Sect. 15	Page 2 - 6
Appendix G.	Three (3) Semi-automatic Welding Machines.	Sect. 15	" 7 & 8
Appendix H.	One Five (5) Ton Welding Positioner.	Sect. 15	" 9 - 14
Appendix J.	One 600 amp. Push Pull M.I.G. Welding Machine.	Sect. 15	" 15 - 17

9. Sudden reductions in aluminium sections can well mean stress risers. This particularly applies to welding runs at starting and finishing ends of manual welding; improperly designed, these inherent defects are liable to fail in highly stressed joints.

10. Both T.I.G. and M.I.G. automatic welding processes can be automated so that the welding head can be traversed along a weld seam. During the welding of long seams, distortion - a major consideration - does occur, and shop practice is to guide the welding head with a cross-slide arrangement.

11. Constant vigil is necessary to keep in touch with the latest welding machines and techniques. Naturally, machines of local manufacture are preferred if available. Table 18 indicates examples of machines purchased in Australia, and others purchased from the United Kingdom, West Germany, France, Switzerland and the United States of America.
When purchasing machines, it is considered advisable that they have a little spare capacity over and above their allotted tasks rather than have "a boy doing a man's job".

TABLE 18. MACHINE TOOLS USED IN MODERN ALUMINIUM (1976) WELDING TECHNIQUES.

MACHINE	MAKER	AGENT	NO. IN SERVICE	LAST PURCHASED	LAST MACHINE PURCHASE PRICE
Linde Sigmatic	Linde, West Germany	C.I.G.	1	1964	$ 3 360
Spool Gun Welding Unit	Oerlikon, Switzerland	A.&.I. Perkins	2	1967	$ 695
"Migmatic 500"	Rowenarc, England	Murex Aust. Pty. Ltd.	11	1969	$ 3 400
Pneumatic Weld Shaver	Zephyr Mfg. Co., California U.S.A.	G. Blackwood & Son Ltd. Collingwood, Victoria	2	1971	$ 1 910
Rotators 10 Ton	Methods Positioners Pty. Ltd., N.S.W.	C.I.G.	2 sets	1974	$ 3 528
F.A.F.	French Manufacture	Australian Liquid Air	2	1974	$ 4 517
Automatic Welding Positioner	Methods Positioners Pty. Ltd., N.S.W.	C.I.G.	1	1974	$ 8 750
Senior Auto. Welding Manipulator (Boom Welder)	Methods Positioners Pty. Ltd., N.S.W.	C.I.G.	1	1975	$21 606
Weldmatic Arc Welder	Welding Industries of Australia	A.&.I. Perkins	1	1975	$ 4 220

SUNDRY ASSESSMENTS.

In the competitive field of estimating, quick assessments and approximate deductions are necessary for the dual purpose of a "feasibility cost" in the first instance and a rough check on final cost calculations.

For such considerations in railway rolling stock :-
Aluminium averages 0.10 lbs/in^3
Aluminium in design 0.15 lbs/in^3 equal in design requirements to steel
Mild steel averages 0.30 lbs/in^3 (485 lbs/ft^3 = 0.28 lbs/in^3)

NOTE: Therefore, where mild steel sections can be replaced with aluminium, the saving in weight can be considered as one-half the weight of steel when replaced by 'equal-in-strength' aluminium sections.

Current material costs		Proportion
Mild Steel	$250 per tonne	1
		:
Aluminium	$1500 per tonne	6

TABLE 19. MATERIAL WEIGHTS AND COSTS ASPECTS COMBINED

DENSITY LBS/IN^3	EQUIVALENT WEIGHTS	EQUIVALENT CONTAINER	
		COSTS	PROPORTION
0.10	Let W = Weight of aluminium portion	$1500 W plain	2
0.15	then 1½W = Weight of aluminium "equal in strength"	$2250 W strengthened	3
0.30	and 3W = Weight of mild steel in steel design	$ 750 W steel	1

	Mild Steel	:	Aluminium
NOTE: Therefore, weights for similar design strength	2	:	1
and costs for similar design strength	1	:	3

Where weights of assemblies of any given vehicle, aluminium or mild steel, are known quick comparison can be made of its counterpart.

Example: "Class XC" Aluminium Wagon :- Tare 17 Ton 2 cwt, Load 62 Ton 18 cwt, Gross 80 Ton

Two bogies	=	19 700 lbs	=	8.795 Tons	)
Draft Gear	=	3 000 lbs	=	1.339 Tons	) = 10.58 Tons
Brake Gear	=	1 000 lbs	=	0.446 Tons	)

For Proportions

Tare	17.10 Tons	÷ 6.52	=	2.623	Say 2.6	or	13
Hardware	10.58 Tons	÷ 6.52	=	1.623	1.6		: 8
Aluminium	6.52 Tons	÷ 6.52	=	1.000	1.0		: 5

If designed in steel = 6.52 x 2 = 13.04 Tons

TABLE 20. APPROXIMATE TARE TO GROSS WEIGHT COMPARISONS

e.g.	Aluminium XC			Steel Counterpart		
	Weight	Proportion	Units	Weight	Proportion	Units
Tare	17	2.6	13	23½	1.8	9
Hardware	10½	1.6	8	10½	0.8	4
Container	6½	1.0	5	13	1.0	5
	5/13 = 38.5%			5/9 = 55.5%		

NOTE: In this example the steel container in a wagon increases its own weight up to 17% of the total wagon weight and decreases the pay load by a weight approximately equal to the weight of aluminium in an aluminium built wagon.

INFLATION - KEEPING TRACK WITH

Broadly, estimating & costing are divided into three divisions, Materials (M) and Wages (W) and Overheads (O). The prices of materials are fixed costs about which the manufacturer can do little, without affecting design efficiency. A small percentage is added as insurance against sudden and unforeseeable price rises.

Wages and Overheads are usually linked together and any contingencies generally on-costed to the Overheads. Therefore, it behoves both Designer and Manufacturer to consider costly man-hours as a most important factor.

A C.P. (Critical Path) Chart should clearly set out in advance Design Time, Materials Lead-time, Construction times and Output of units to maximise production and minimise costs.

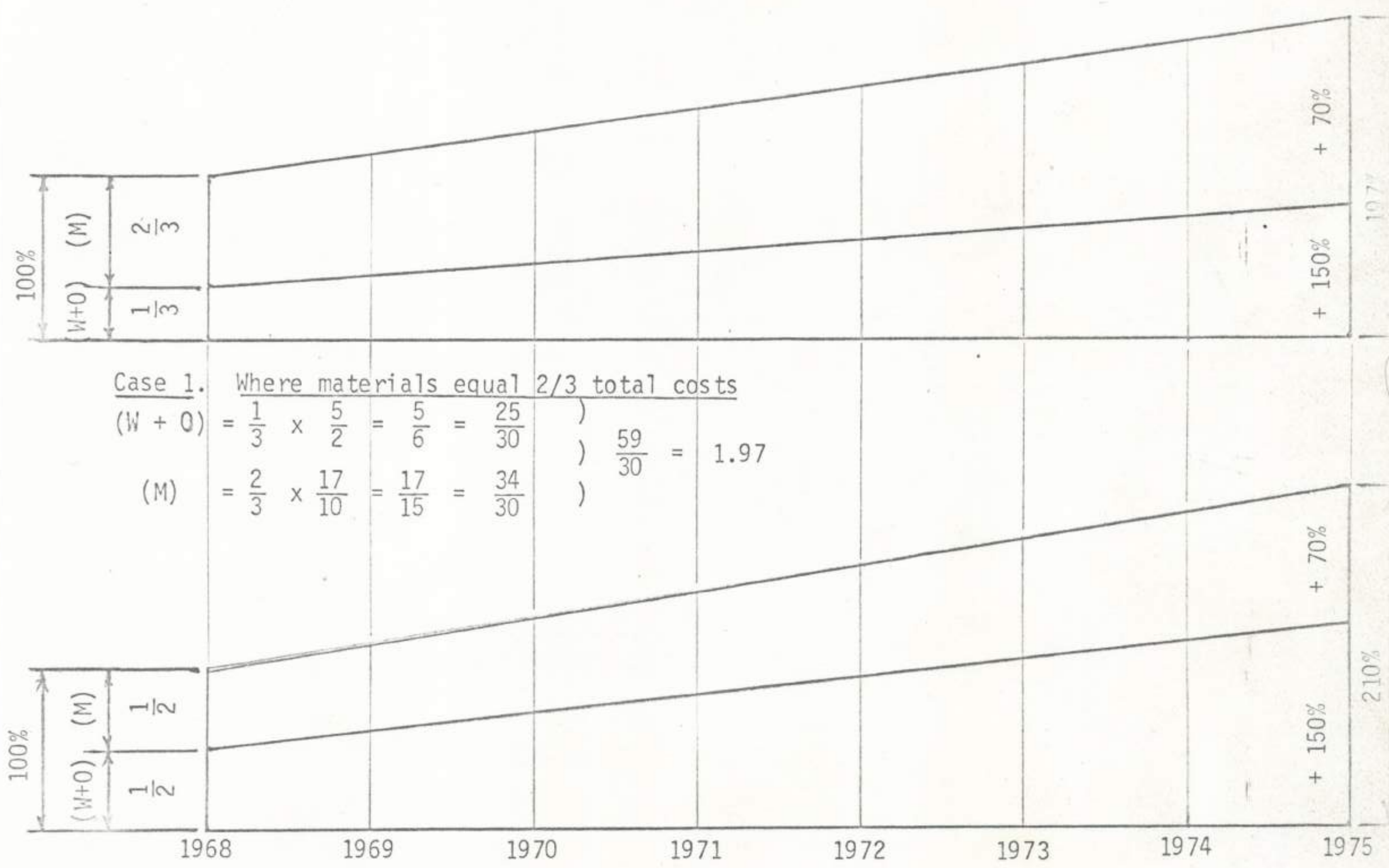
The proportions of "W + O" in relation to "M" fall roughly within the two orders shown in Diagram 4 (in straight lines for simplicity) depending on the complexity of the design.

In Case 1, materials take up two-thirds of the total costs, and one-third by Wages and Overheads, and in Case 2 materials take up one-half of the total costs, and one half by Wages and Overheads.

NOTE: Between 1968 and 1975 Wages in Western Australia increased by 150%, Materials by 70% and as both graphs indicate, total costs have increased from 1.97 to 1 and 2.1 to 1 respectively against 1968 costs. Therefore, the comparison of 2:1 is a handy current guide but must of course be modified as any price change occurs to either Labour or Materials or Shop Overheads.

DIAGRAM 4

INFLATION COSTS 1968 TO 1975



Case 1. Where materials equal 2/3 total costs

$$(W + O) = \frac{1}{3} \times \frac{5}{2} = \frac{5}{6} = \frac{25}{30}$$

$$(M) = \frac{2}{3} \times \frac{17}{10} = \frac{17}{15} = \frac{34}{30}$$

$$\frac{59}{30} = 1.97$$

Case 2. Where materials equal 1/2 total costs

$$(W + O) = \frac{1}{2} \times \frac{5}{2} = \frac{5}{4} = \frac{25}{20}$$

$$(M) = \frac{1}{2} \times \frac{17}{10} = \frac{17}{20} = \frac{17}{20}$$

$$\frac{42}{20} = 2.1$$

ROLE OF WESTERN AUSTRALIAN GOVERNMENT RAILWAYS (WESTRAIL) IN THE GROWTH OF ALUMINIUM PRODUCTION IN WESTERN AUSTRALIA

The construction of the Kwinana Alumina refinery began on a site 22 miles (35 km) south of Perth in December, 1961 and in less than two years later, (October 1963 to be precise), the first unit was completed and production of alumina began at a rate of 210 000 tonnes per annum.

Westrail, in cooperation with Alcoa and the Western Australian Government built a railway linking Kwinana with the bauxite mining site at Jarrahdale. The haulage of bauxite commenced with 31 XBC composite constructed wagons and 1 R class locomotive (2025 H.P. derated to 1950 H.P.)

Several months after commencement of bauxite operations, the first shipment of alumina left Kwinana via the southern coast of Australia to the Point Henry Smelter in Victoria, Australia and on 30th March, 1964, the first of many export shipments ex Western Australia was loaded for Japan.

As new export markets were being won Kwinana's alumina export production capacity was multiplied seven times between the years 1963 to 1972 to reach 1 400 000 tonnes per year.

To achieve this, Westrail purchased new and larger locomotives viz. "D" class (derated to 2200 H.P.) from G.M.H./Clyde and increased the block unit trains to handle the bauxite haulage requirement now in excess of 4.5 m tonnes per year, Jarrahdale to Kwinana.

One small unit train with one D class locomotive can haul 35 aluminium constructed wagons with a nett bauxite capacity of 2212 tonnes each haul. Three trips per day is at present being achieved making the daily haul 6636 tonnes, with the small unit train (28 XC and 7 XBC).

The large double unit train (56 XC and 14 XBC) with 2 D class locomotives, hauls a train load of 70 aluminium constructed wagons and the nett bauxite capacity on each train 4424 tonnes. The loading and unloading facilities are almost at perfection point and three trips per day from Jarrahdale to Kwinana and return are quite easily achieved. The double unit train delivers 3 x 4424 tonnes = 13 272 tonnes.

Therefore, the two trains convey 6636 + 13 272 = 20 908 tonnes daily Jarrahdale to Kwinana for refinement.

On a 5 day week basis this is in excess of 100 000 tonnes of ore and the target of 5 million tonnes can be achieved if necessary.

Working a 7 day week the capacity can be raised to 7 million tonnes but this is not necessary, nor is it desirable under the present climate of industrial wage decisions and week-end penalty rate payments.

The pooling diagram showing the schedules appears in Diagram 5. The small unit train of 35 wagons appears at the bottom of the diagram and the double unit train of 70 wagons (56 XC and 14 XBC) appears in the middle of the diagram.

Nine years later, 1970, construction commenced on Alcoa's second refinery at Pinjarra, 55 kms south of the Kwinana headquarters of Alcoa and 20 miles inland from the Indian Ocean.

Situated on a flat plain at the foot of the Darling Range, the new refinery has the potential to become one of the largest and most modern refineries in the world. Yet it has been designed to expand unobtrusively in the heart of a 12 500 acre (5058 hectares) Company owned sheep and cattle grazing property to preserve the aesthetics of the rural countryside.

The Pinjarra refinery was commissioned in May, 1972 and by 1973 had a capacity of 600 000 tonnes of alumina per annum almost three times greater than the initial production of the Kwinana plant of 1963.

This capacity of 600 000 tonnes of alumina per annum was produced from two units, construction of a third unit was completed in 1974 and a further unit, making a total of 4 units, was completed at the end of 1975 and full production at Pinjarra with a capacity of 2 000 000 tonnes of alumina will commence early 1976.

The combined capacity of the Kwinana plant 1.4 million and the Pinjarra refinery will stand at 3.4 million tonnes per year, making Alcoa the biggest alumina producer in the Southern Hemisphere.

Unlike the haulage of bauxite ore only from Jarrahdale to Kwinana for refinement to Alumina, the Western Australian Government Railways (Westrail) were equal to the task and immediately designed and constructed several types of wagons of aluminium content to meet the challenge.

The various classes of wagons designed and built in Westrail's own modern workshops at Midland, were aluminium XF wagon nett content of 62 tonnes alumina .
aluminium XFL, lime pellet wagon of 52 tonnes nett lime
steel JK, caustic wagon of 52 tonnes nett caustic

The geography and the terrain of the country to be traversed between Kwinana and Pinjarra apart from a few small rivers and creeks was ideal for maximum tonneages per locomotive.

In the journey Kwinana to Pinjarra the initial capacity was 27 XF empty wagons plus 4 XFL lime loaded plus 8 JK tankers of caustic; the ruling gradient being 1:40.

One D class diesel locomotive 2200 H.P. rating hauled the unit train with considerable ease and after several test loads the capacity was increased in stages to 28 XF, to 30 XF and in late December, 1975 approval was given to increase the capacity of the alumina unit train to 31 XF loaded ex Pinjarra plus the empty caustic and lime wagons, making the gross haulage tonneage 2850 tonnes for the D class locomotive Pinjarra to Kwinana.

These are truly fantastic haulage figures for one D class locomotive. Two return trips are being achieved daily.

The excellence of the aluminium constructed wagons and the very low tare ratio to the alumina content, makes this a very viable and lucrative proposition.

The XF alumina carrying wagon with a tare of approximately 18 tonnes and alumina content of 62 tonnes gives an all up weight of 80 tonnes, which is equivalent to 20.00 tonne axle weight on a very well maintained and ballasted track.

On these figures, the single unit train runs two trips daily, and during the months of December, 1975 and January, 1976 a full programme for 7 days per week was necessary to meet the upward surge of alumina production from the Pinjarra refinery.

The proven annual haulage capacity is as follows :-

<u>ALUMINA</u>

31 XF loaded x 62 tonnes = 1922 per trip	=	3 844 tonnes daily
Weekly x 7 days	=	26 908 tonnes daily
Yearly x 50 weeks (average)	=	1 345 400 tonnes daily

<u>CAUSTIC</u>

8 JK loaded x 53 tonnes = 424 per trip	=	848 tonnes daily
Weekly x 5 days only	=	4 240 tonnes daily
Yearly x 50 weeks (average)	=	212 000 tonnes daily

<u>LIME</u>

4 XFL x 52 tonnes	=	208 tonnes daily
Weekly x 5 days only	=	1 040 tonnes daily
Yearly x 50 weeks (average)	=	52 000 tonnes daily

SECTION 11. (Cont.)

It will be noted that Westrail is at present capable of hauling between 5 million to 7 million tonnes of bauxite Jarrahdale to the Kwinana refinery plus 1 345 000 tonnes of Alumina ex the Pinjarra refinery to the Kwinana headquarters

New XF wagons are being issued from the Midland Workshops and a second unit train with a smaller locomotive is being requisitioned ready to commence when the programmed target of 2 million tonnes of alumina ex Pinjarra is obtained.

Of course, like every other mining industry, there are production surges of alumina and the occasion arises where Alcoa has to call on private road hauliers to meet the increased alumina production ex Pinjarra.

Shipping targets are being met, thanks to the excellent transport facilities provided by Westrail.

Export of alumina viz. 1.4 million tonnes from the Kwinana Refinery plus 2 million from the Pinjarra Refinery is keeping well abreast with production and 300 000 tonnes per month ex Alcoa's private wharf at Kwinana is now a common achievement.

Alcoa of W.A. ships alumina to :-

BAHRAIN
IRAN
JAPAN
UNITED STATES OF AMERICA
ARGENTINA

Australia is now one of the 3 major bauxite producing nations of the world, but increasing emphasis is being placed on expanding alumina production.

It is possible that Australia, as a nation, will become the largest alumina producing and exporting nation in the world within the next ten years.

Leading metal manufacturers and major industries such as Westrail are quick to appreciate the excellence of aluminium and this fact is borne out by the excellent results being achieved with aluminium constructed rail wagons for the transport of bauxite, alumina and many other commodities.

ALCOA - CALCINE. Alumina, Caustic and Lime Loads from Traffic Operator's point of view

Sample Loads		Empty Direction	Sample Loads		Loaded Direction
Brakevan ZS	=	15	Brakevan ZS	=	15
29 XF x 18	=	522	8 JK Empty x 26	=	208
8 JK Loaded	=	640	29 XF x 81	=	2349
			4 XFL Empty x 18	=	72
	=	1177 tonnes		=	2644 tonnes
Ruling Grade		1600 tonnes - 1975 -	Ruling Grade		2660

Brakevan ZS	=	15	Brakevan ZS	=	15
29 XF Empty x 18	=	522	31 XF loaded	=	2511
8 JK Loaded	=	640	4 XFL Empty x 18	=	72
4 XFL	=	280			
		1457			2598

SECTION 11. (Cont.)

Test loads during December, 1975 now increased to 2850 tonnes after full evaluation.

Figures below indicate tonneages hauled annually Pinjarra to Kwinana only.

ALUMINA 1975.		ALUMINA 1976.	
	29 XF		31 XF
	8 JK		8 JK
	4 XFL		4 XFL
	B/Van		B/Van

29 XF @ 62 tonnes	=	1798 tonnes per trip	31 XF	=	1 922
Second trip	=	1798 " " "		=	1 922
per day	=	3596 " " "		=	3 844
(x7) per week	=	25 172	(x7)	=	37 908
(x50) per annum	=	1 258 600	(x50)	=	1 345 400

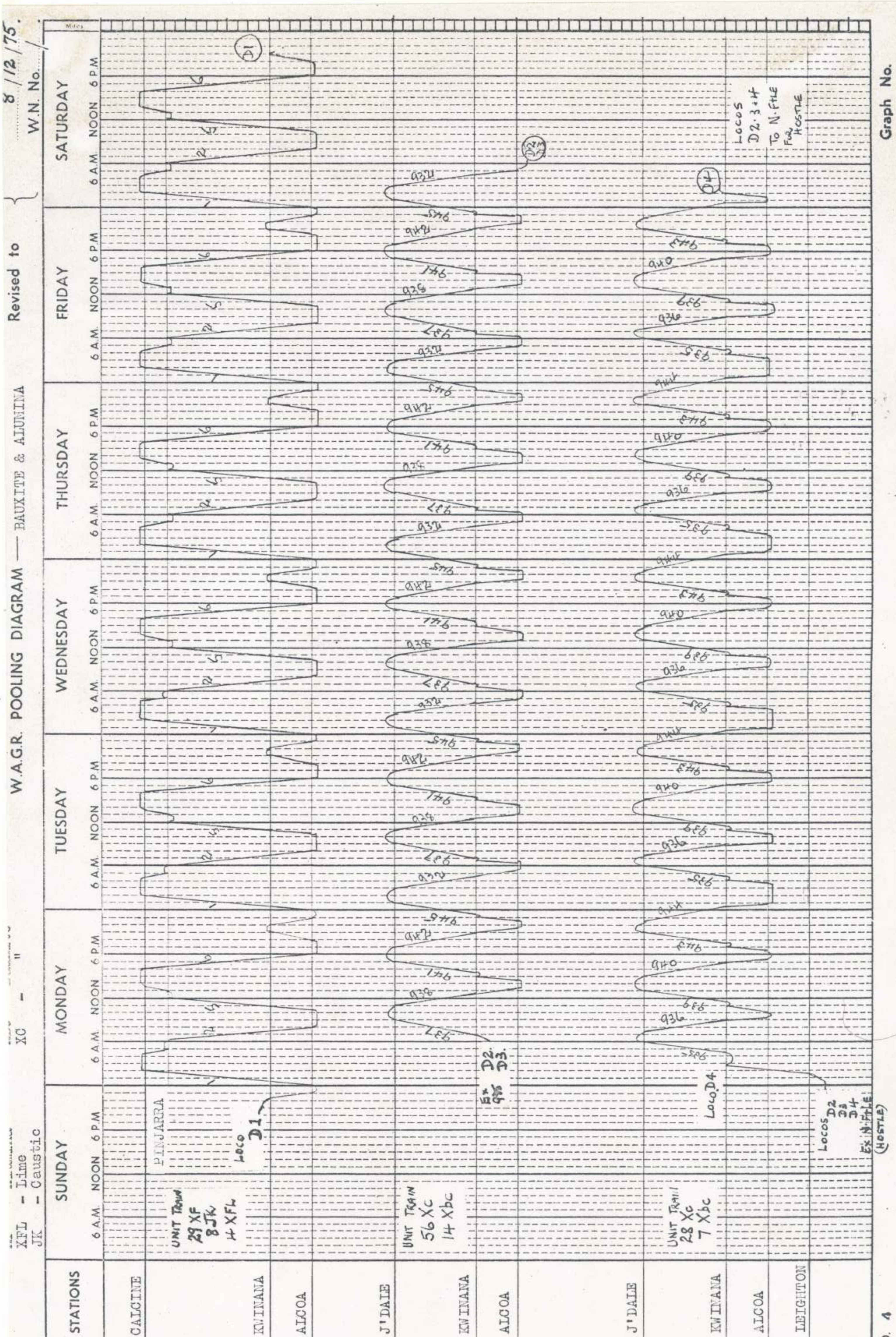
CAUSTIC

8 JK @ 53 tonnes	=	424 tonnes per trip	8 JK	=	424
Second trip	=	424 " " "		=	424
per day	=	848 " " "		=	848
(x5) per week	=	4 240	(x7)	=	5 936
(x50) per annum	=	212 000	(x50)	=	296 800

LIME

4 XFL @ 52 tonnes	=	208 one trip Daily only	4 XFL	=	208
(x5) per week	=	1 040	(x7)	=	1 456
(x50) per annum	=	52 000	(x50)	=	72 800

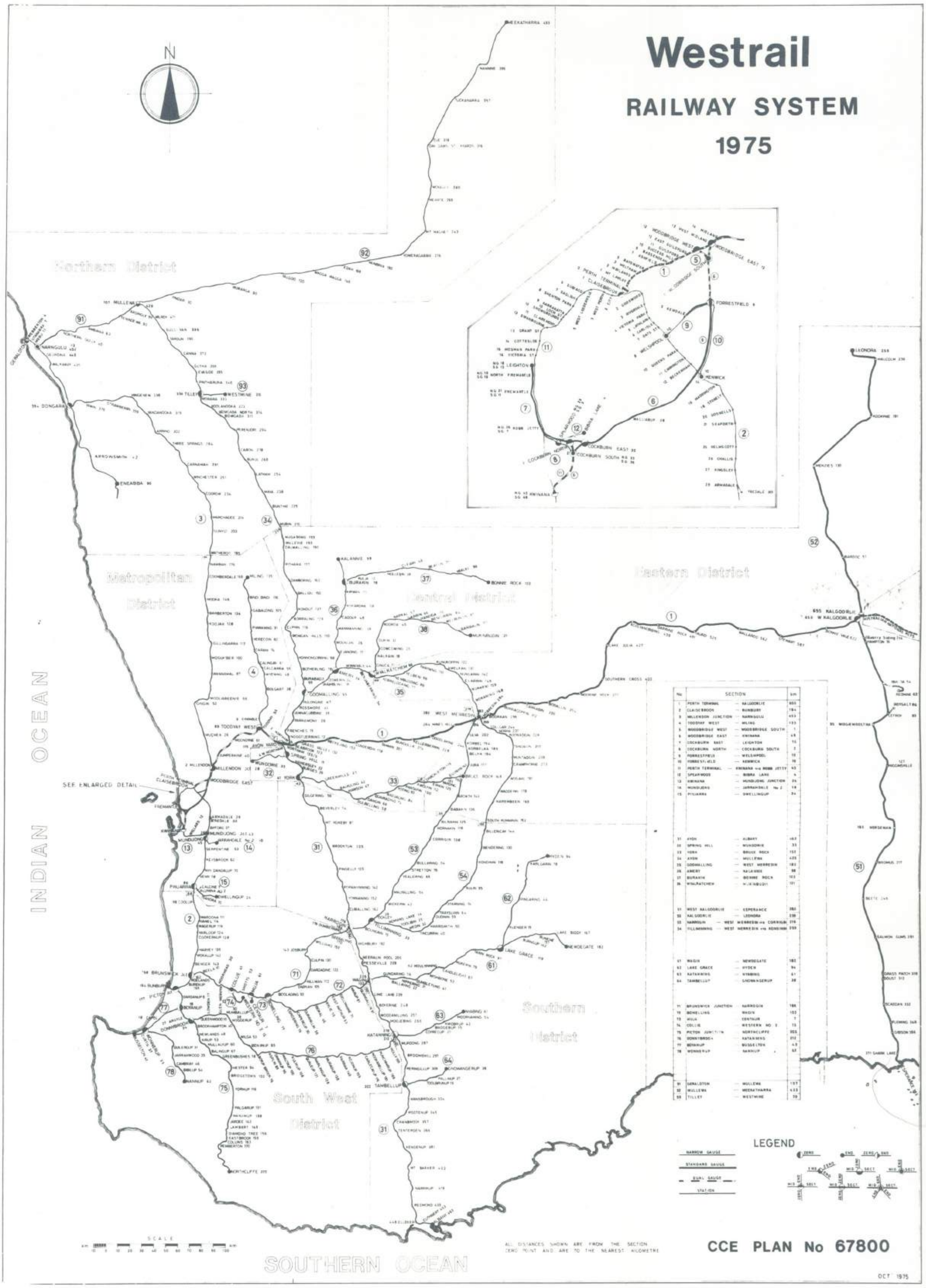
Diagram 5.


W.A.G.R. POOLING DIAGRAM — BAUXITE & ALUMINA
Revised to 8/12/75.
W.N. No.
STATIONS
SUNDAY
MONDAY
TUESDAY
WEDNESDAY
THURSDAY
FRIDAY
SATURDAY
CALCINE
PINJARRA
KWINANA
ALCOA
J'DALE
LEIGHTON
XFL - Lime
JK - Caustic
Graph No.
P.D. 4
CTM 99/71

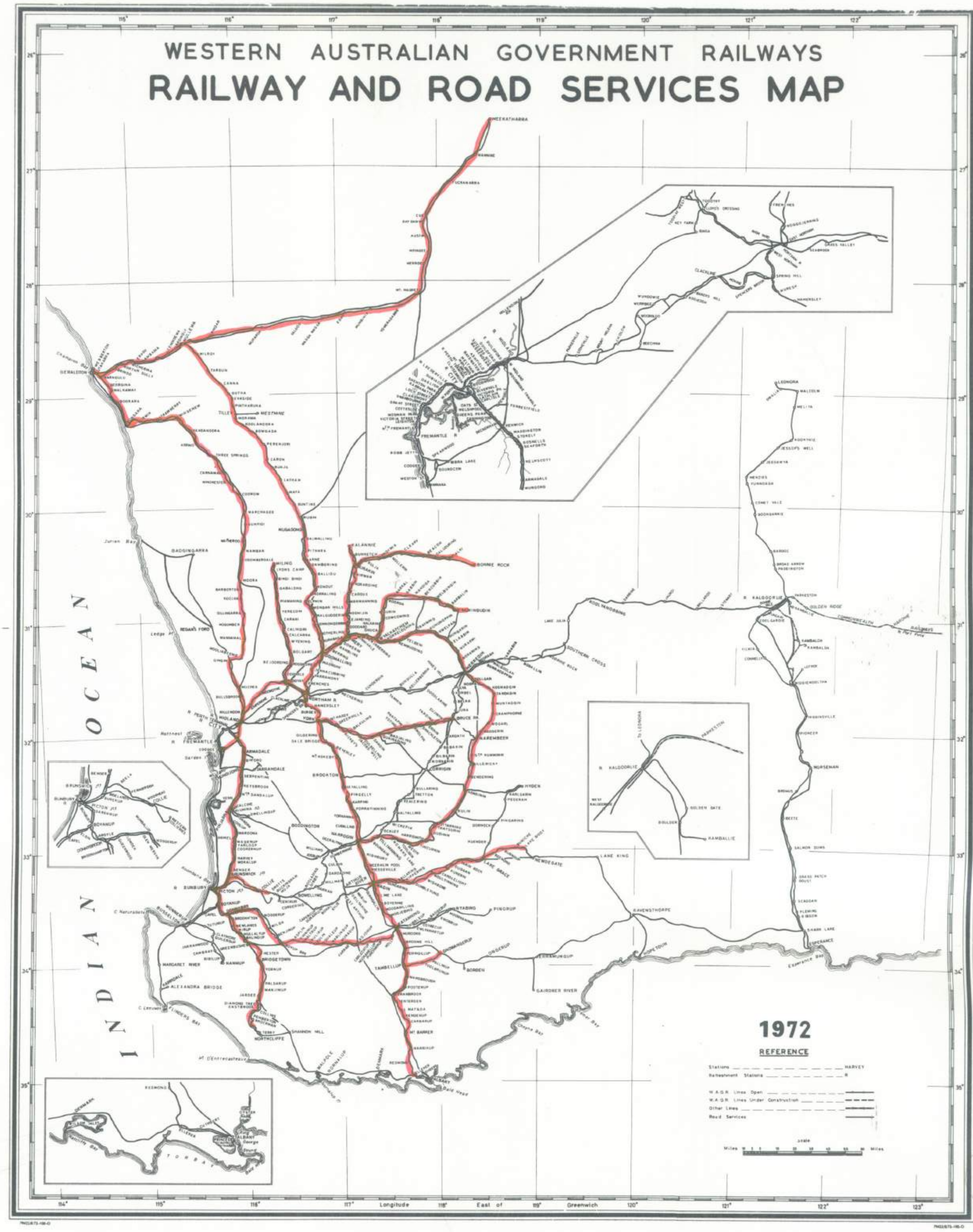
SECTION 12.

ALUMINIUM WAGON ROUTES IN WESTRAIL

Maps are included indicating the Westrail Railway System and routes over which aluminium wagons run in service.

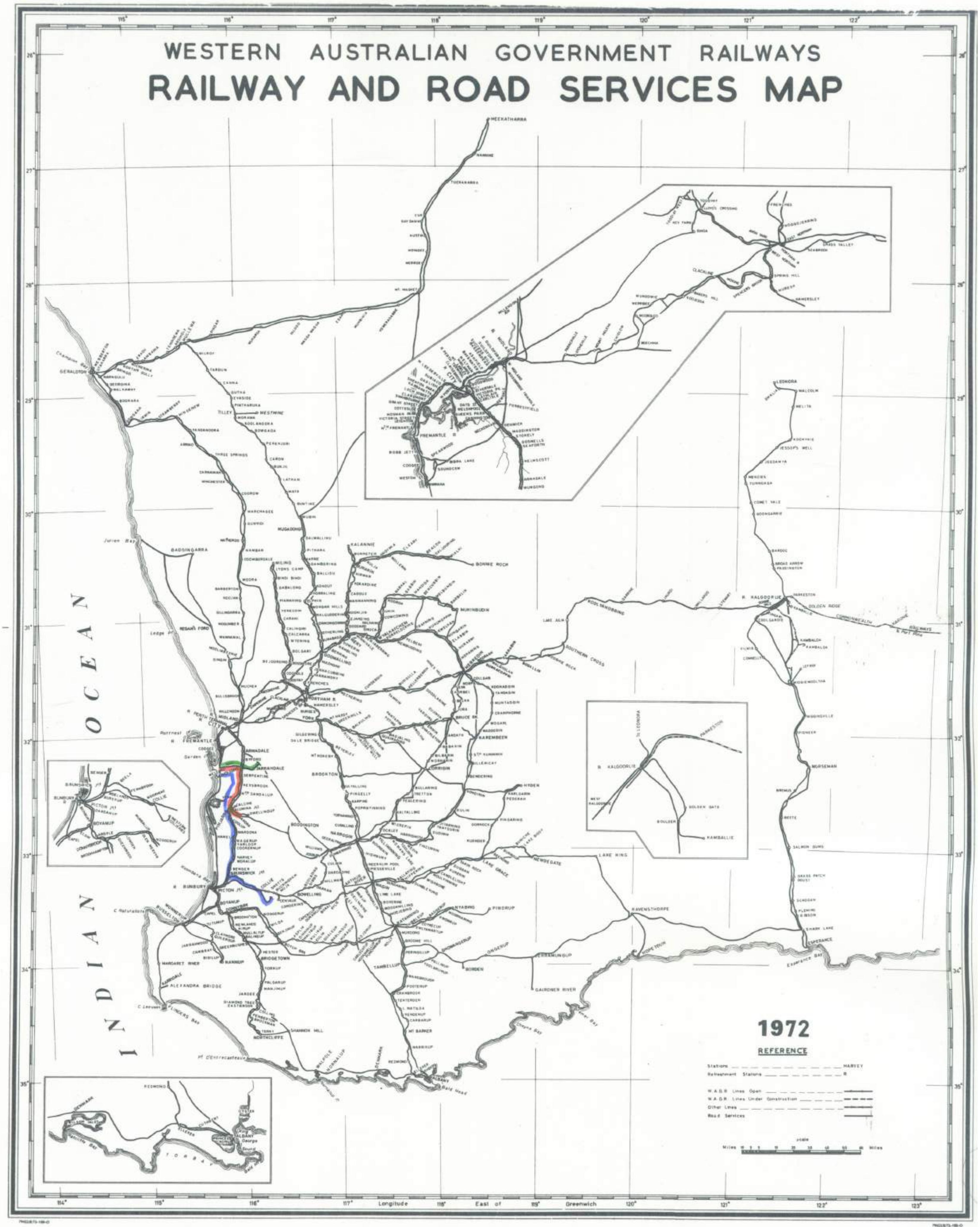

Westrail
RAILWAY SYSTEM
1975
N
Northern District
Metropolitan District
Central District
Eastern District
Southern District
South West District
INDIAN OCEAN
SOUTHERN OCEAN
SEE ENLARGED DETAIL
LEGEND
CCE PLAN No 67800

Map 1.



JPA NARROW GAUGE TANKERS

MAP 2.

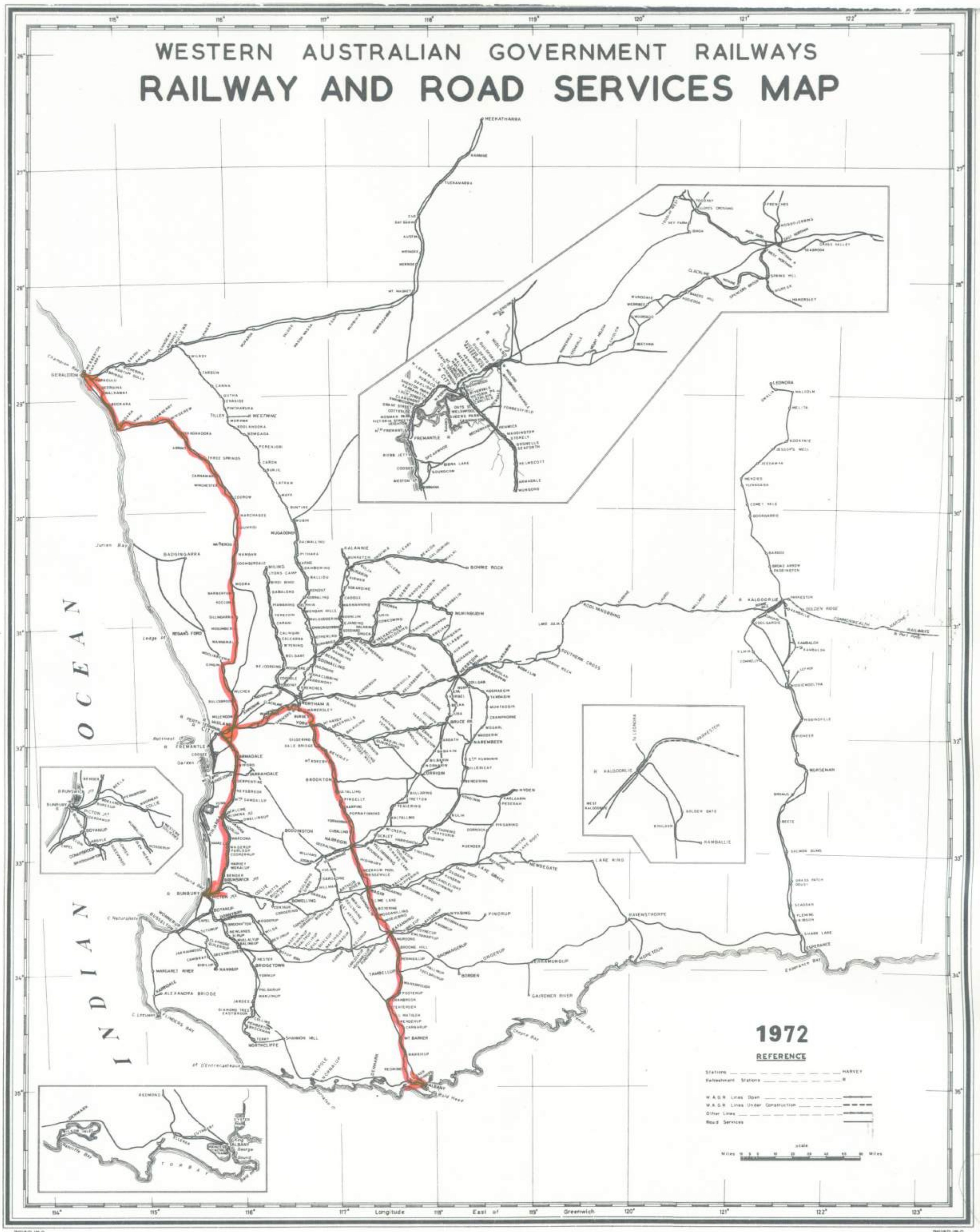


XC, XBC. BAUXITE, JARRAHDALE TO KWINANA (green line)

XF, XFL. ALUMINA AND LIME, PINJARRA TO KWINANA (red line)

XN. COAL, COLLIE TO ROBB JETTY (SOUNDCEM) (blue line)

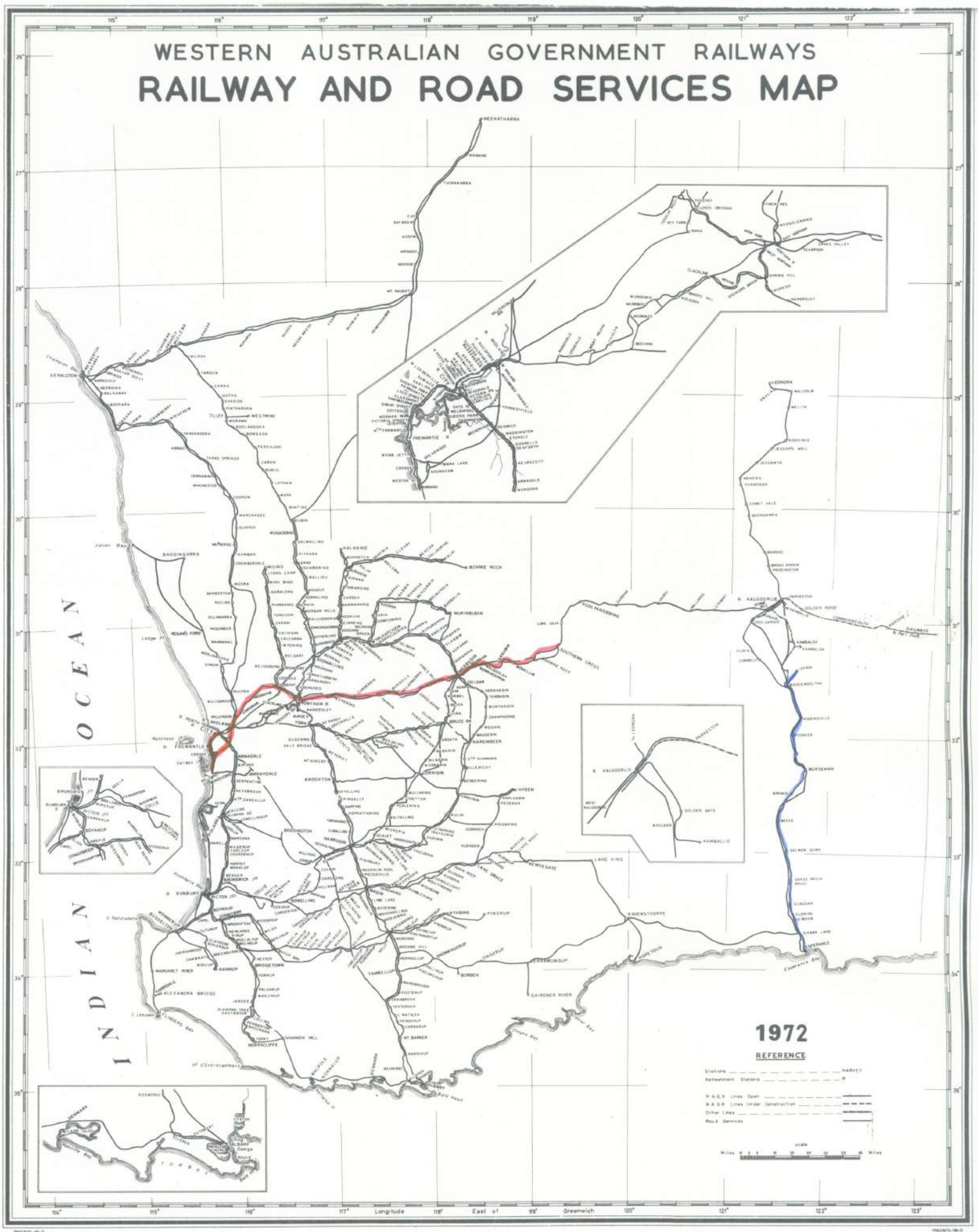
MAP 3.



XR. CEMENT, RIVERVALE AND SOUNDCEM TO

BUNBURY, GERALDTON & ALBANY

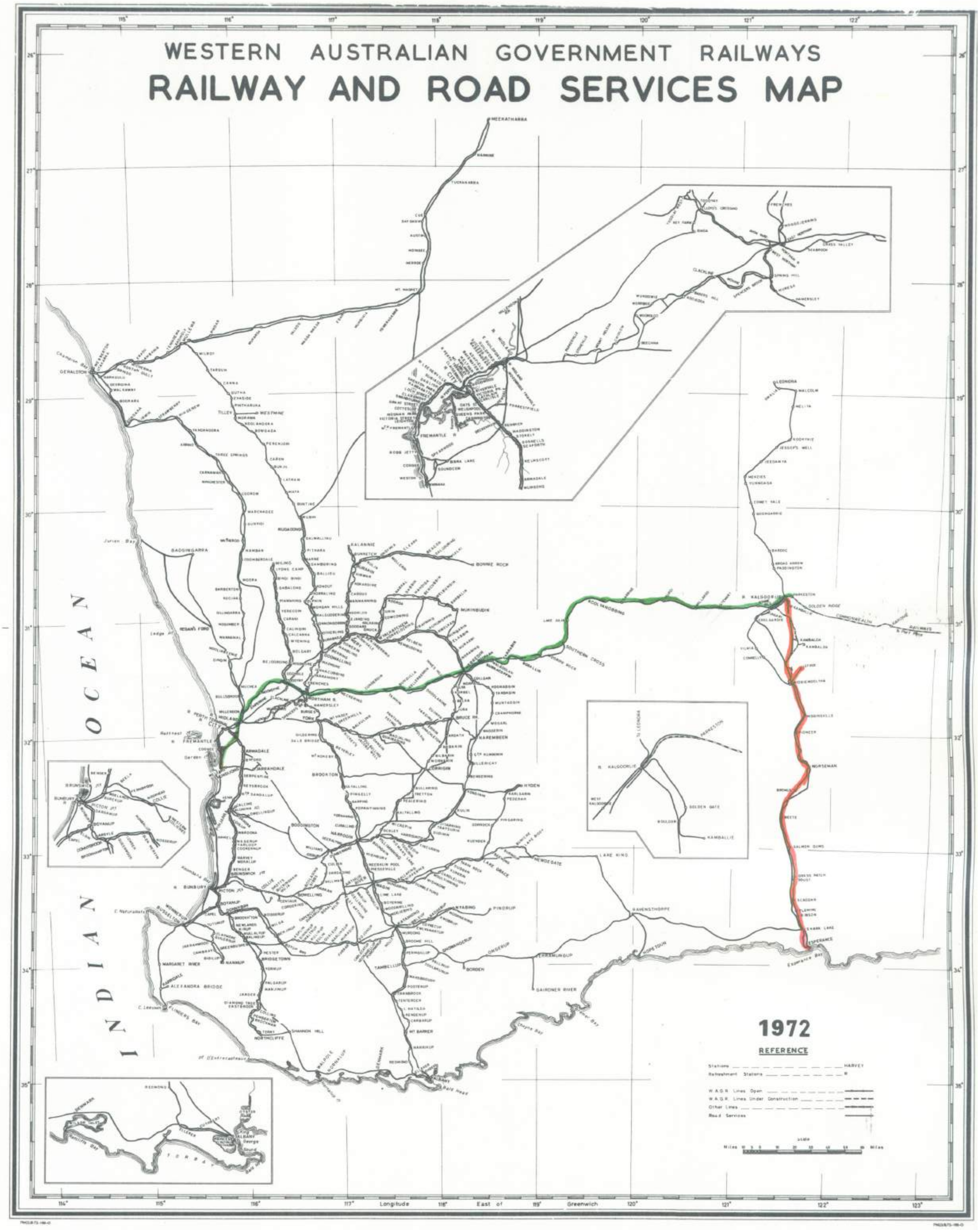
MAP 4.



WWA. STANDARD GAUGE. GRAINS TO ALL POINTS BETWEEN LEIGHTON AND SOUTHERN CROSS

WL. SALT, LEFROY TO ESPERANCE

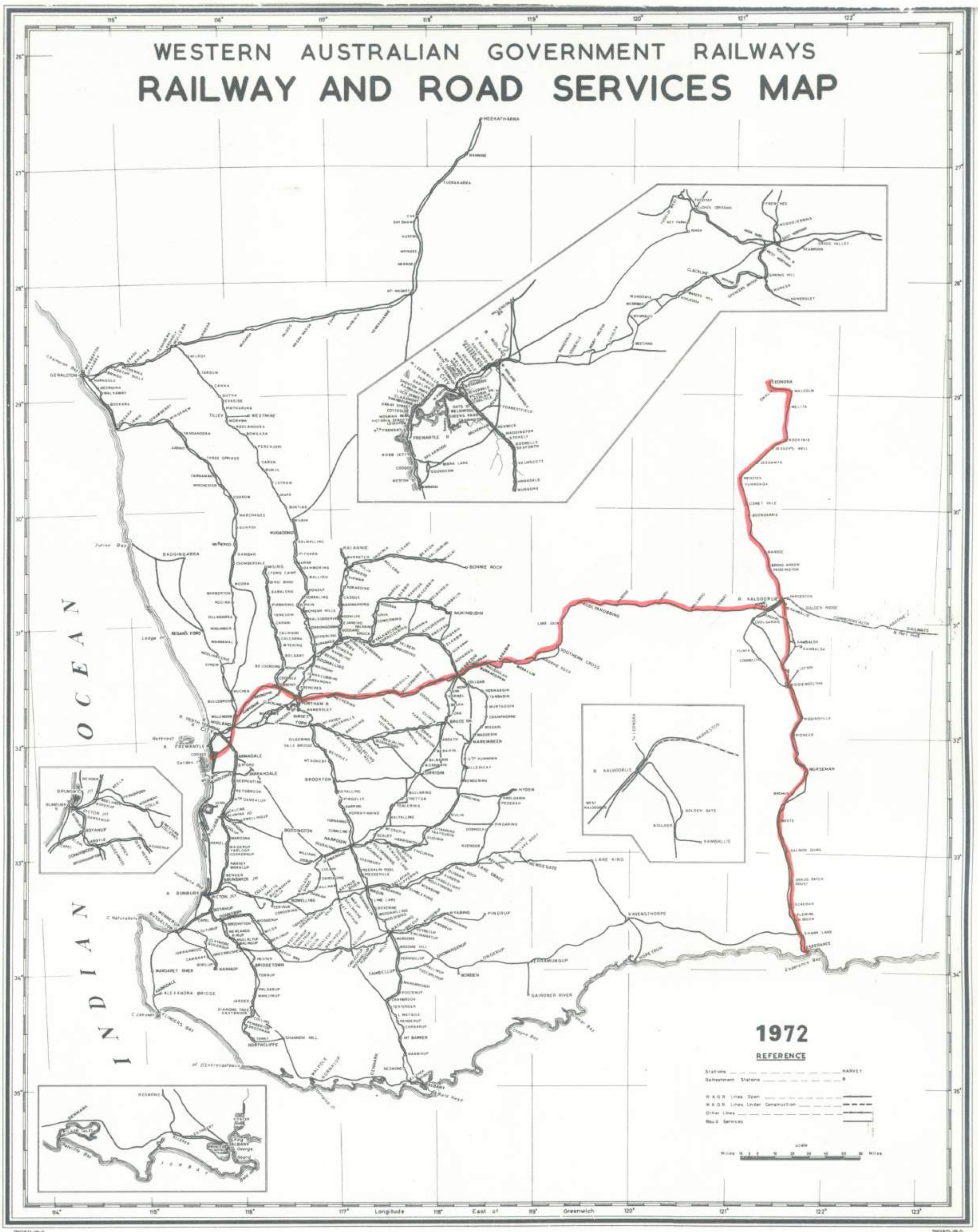
MAP 5.



WJP & STANDARD GAUGE TANKERS, FREMANTLE TO KALGOORLIE

WJL, WJK, KALGOORLIE TO ESPERANCE

MAP 6.



WK. CEMENT WAGONS FROM SOUNDCEM

WJD & ALL TYPES STANDARD GAUGE TANKERS FROM FREMANTLE TO KALGOORLIE, KALGOORLIE TO LEONORA & KALGOORLIE TO ESPERANCE

COST BENEFITS AND EVALUATIONS

ALUMINIUM VERSUS STEEL IN WAGON CONSTRUCTION - THE ECONOMIC VIEWPOINT

"Selection of the optimum wagon type is of major importance in unit train bulk haulage projects. Design is governed by such criteria as the maximum load/tare ratio within the maximum axle load limitations determined by the track structure, low operating and maintenance cost and high operational reliability." (*)

The choice of material for wagon construction is limited to two basic metals - Aluminium or Steel. The former has the advantage of the best load/tare ratio (holds more of the product per unit of its own weight) but the latter has strength properties that result in a shorter wagon design for a fixed load/tare ratio. (The length of the wagon is important in relation to the lengths of crossing loops and terminal sidings that are available and which provide a constraint on train length, and therefore on the number of wagons that can be used to make up the train.)

In order to illustrate the economic aspects of the choice a general transport task has been evaluated and is described at Exhibit 1. Cost figures for this simulation indicate that the Aluminium wagon is financially more attractive than the steel wagon to operate and maintain, by 15.1 cents per tonne hauled, and that the aluminium wagon alternative is favoured if the capital cost differential between the two alternatives is no more than $16 000 per wagon. (Exhibit 2 illustrates in graphical form the maximum cost increase allowable for aluminium wagons). Recent information relative to the wagon characteristics outlined suggests that this is the case.

These results, however, must be viewed in the light of the underlying assumptions, and any conclusion must be subject to the following considerations:

- Not all transport tasks are conducive to aluminium wagon utilisation. Because of the possible length constraint, there may be situations where either additional costs for extending crossing loops or terminals, or because of reduced wagon numbers per train additional costs in train running, are incurred if aluminium wagons are utilised.

- Costs have been derived using a system average basis and expressing the results with gross tonnage as the variable parameter. Whilst these cost units are acceptable (with a tolerance of 15-20%) over large increments, their accuracy over a small range is suspect. (Aluminium wagons are likely to reduce the gross tonnage by 15-20%).

- The wagon maintenance benefit, at this stage, is based on engineering estimates. Existing aluminium wagons have not been in service long enough to substantiate these.

- The interest on capital (discount rate) and amortisation period are important factors which vary depending on the situation. The illustrative example uses a 10% discount rate and a 20 year wagon life.

- Although the residual value of aluminium wagons is considered to be greater than steel the illustrative example does not differentiate between residual values.

- Investment decisions are almost always taken under conditions of capital restraint so that on occasions the less capital expensive alternative might be preferred on other than economic grounds.

The economic merits of aluminium wagon construction should not preclude the consideration of the non quantifiable benefits that might exist:

- The ability to have more wagons on a consist, to satisfy the same transport task, would enable the number of trips to be reduced and creates the opportunity for the alternative utilisation of the locomotive and brakevan.

* Reference Rail Transport of Minerals 1972 by W.I. McCullough

- The reduced incidence of maintenance of the aluminium wagons results in a requirement for fewer "spares", increases the time that wagons are "on traffic", and reduces congestion in the maintenance workshop.

- Chemical reaction between the wagon and its contents (e.g. coal) is reduced by using aluminium rather than steel in wagon construction.

As costs are sensitive to a number of parameters (data accuracy, discount rates, planning horizon) and there are always significant non-economic considerations, no general conclusion between the above alternatives can be made. Each case must therefore be considered on its merits and with due regard to the uncertainties associated with it. Thus, although there are circumstances in which aluminium wagons can be financially advantageous when compared to steel, there is no general rule that ensures that this is the case in all situations. It is therefore necessary to evaluate each alternative for any particular project.

EXHIBIT 1 ILLUSTRATIVE EXAMPLE

PROJECT A X Y

Consider the transport of a product, A, a distance 200 km from X to Y. It is estimated that 450 000 tonnes will be transported annually, constant over a 20 year period.

The following operating parameters are evident:

- wagon characteristics

	aluminium	steel
load (tonnes)	57	53
tare (tonnes)	19	23
length (metres)	16	15

- a single locomotive is capable of hauling 2600 gross tonnes.
- the crossing loops and terminal sidings are capable of accommodating a 550 metre train (excluding locomotive and brakevan).

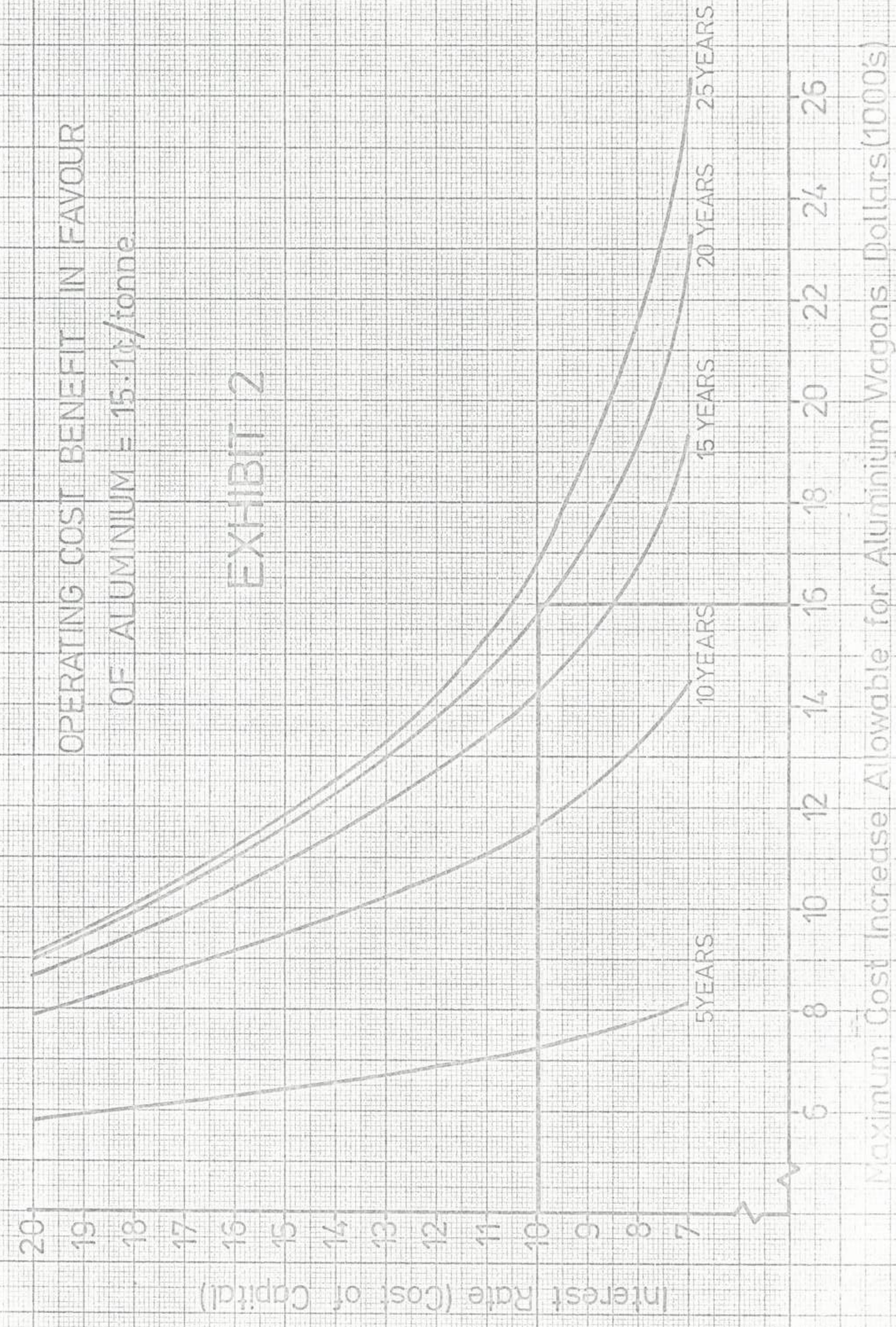
Assuming that 1 trip/day, 5 days/week, 50 weeks/annum working is possible, the following train operations would take place:

	aluminium	steel
max. no. of wagons/loco	34	34
trips/annum required	232	250
overall length of wagons	544m	510m
gross train load	2584t	2584t
net load/train	1938t	1802t

Evaluation of the above transport task comprehending aluminium and steel wagons results in the following incremental benefits (expressed in Equivalent Annual Cost/tonne terms) in favour of aluminium wagons:

train crew labour	1.8¢
locomotive/brakevan maintenance	4.6¢
wagon maintenance	3.9¢
track maintenance	2.7¢
variable overheads	2.1¢
TOTAL	15.1¢

The net benefit in favour of aluminium wagons is 15.1¢. Using a 10% cost of capital and amortising over 20 years, this net benefit can be expressed as the equivalent of a \$590 000 current capital investment. Thus for the fleet of 37 wagons this represents \$16 000/wagon.


OPERATING COST BENEFIT IN FAVOUR
OF ALUMINUM = 15.1¢/tonne.
EXHIBIT 2
25 YEARS
20 YEARS
15 YEARS
10 YEARS
5 YEARS
Interest Rate (Cost of Capital)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
Maximum Cost Increase Allowable for Aluminium Wagons Dollars (1000s)
6
8
10
12
14
16
18
20
22
24
26

SECTION 14.

CONCLUSION

Aluminium freight rolling stock for the tranport of bulk commodities number some 3500 in Australia.

In Western Australia the experience gained with these light-weight vehicles in highly intensive operations of mineral and grain transport in block trains augurs well for the future.

Financial gains from greater pay loads with minimal maintenance and high level performances of current aluminium rollingstock have been made abundantly clear to both the Engineer and the Economist in many cases.

Each case must, however, be thoroughly examined, cost researched and treated as a separate exercise.

The success of the Westrail bauxite haulage operation and the potential of our wagon design has not gone unnoticed. A fleet of sixty (60) one hundred (100) ton gross weight wagons hauling bauxite mined in the Weipa Peninsula, based on the Westrail "Class XC" design, were built by Commonwealth Engineering Pty. Ltd. Queensland.

Considered and continuing experience with aluminium alloy rail vehicles leaves no doubt of the "excellence in aluminium".

APPENDICES.

Appendices have been included in the following order :-

Appendices A and B have been mentioned in the Introduction.

Aluminium wagons on Westrail have been divided in three categories :-

Four examples of D.C.F. exercises have been listed :-

WESTRAIL'S NEW CORPORATE IMAGE

WESTRAIL

A message from The Commissioner of Railways

The Western Australian Government Railways are introducing on 19th September 1975 a new image to the public—an image which I feel has a fresh and co-ordinated approach to demands of modern marketing.

To gain business advantage it has become necessary for the Railway to assert itself to keep at the forefront of the transport industry.

With this thought in mind, we have created a new corporate image for Western Australia's Railway, introducing modern colours to our marketing, a stylised symbol . . . . and a new name.

The new marketing name chosen for the Western Australian Government Railways is WESTRAIL—simple, easy to pronounce, yet retaining its link with the railway and the State.

During the corporate image programme, all railway facilities will come under scrutiny, including locomotives, rolling stock, equipment of all kinds, signs on railway property, promotional printed material—in fact everything which is seen, heard or used by the public and Westrail's staff.

The design of station signs, brochures and major printing will feature one style of type face, its clear-cut lines corresponding to accepted international standards in the transport field and well supported in industry.

The major colours chosen are orange, blue and yellow, which you will see increasingly on all rollingstock, equipment, signs and publicity material.

However, colours and symbols do not stand alone in reflecting a new image, impressions are largely gained from personal contact between staff and public and this is where the introduction and maintenance of our new planned image will be most important. I am confident that with the backing of all staff, WESTRAIL will reflect a new look into the State's railway.

R. J. Pascoe

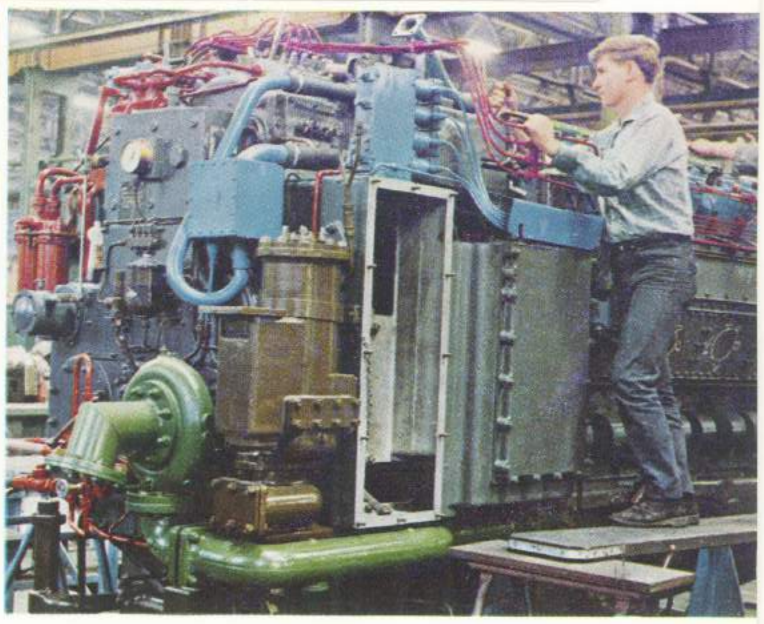
WORKSHOPS EXHIBITION

Westrail

Westrail Workshops Exhibition

Midland

12th November 1975



WESTERN AUSTRALIAN GOVERNMENT RAILWAYS

JH:JJ

CME. 63/2826

3619

13th September, 1974

SECRETARY FOR RAILWAYS

APPENDIX. F.

F/1

Capital Works 1975/76 - Welding Manipulator for Flanging Shop.

1.0 PROPOSAL

Purchase of an automatic welding manipulator for use in the Flanging Shop.

Estimated capital cost = $22 000 (including Installation and Loan Incidentals)

2.0 PRESENT SITUATION

The present situation has been fully explained in the original submission (C.M.E. 63/2826 of 11.8.1971 and 29.3.1973 refers) and is still applicable today.

3.0 ADVANTAGES OF PROPOSAL

The major advantages have already been outlined in the two previous submissions mentioned in (2.0) above. The advantages are again reiterated as follows :-

3.1 Faster welding times i.e. 24 inches per minute for the Manipulator compared with 15 inches per minute for the Bug 'O'.

3.2 Versatility.

3.3 Easily transported.

3.4 Improved weld.

3.5 Less operator fatigue.

3.6 It is considered that set up will be easier and set up times will be reduced, although this aspect has not been included in the D.C.F. exercise.

4.0 DETERMINATION OF WORK LOAD

The work load has been based on similar parameters as the Automatic Welding Positioner (refer C.M.E. 63/2826 of 12th September, 1974). These parameters are outlined below :-

4.1 The work load has been based on an activity level of 120 bogie wagon constructions per annum.

4.2 Savings have been based on welding times saved on wagon construction projects from 1969/70 to 1973/74 and the probable wagon issues for 1974/75.

4.3 It is assumed that, on an average, the savings determined will be the same for future wagon construction programmes. This assumption is based on the fact that the welds determined for the savings are incorporated in fairly common wagon structures.

F/2

5.0 DISCOUNTED CASH FLOW EXERCISE

A Discounted Cash Flow analysis has been carried out as per Appendix 5. This resulted in a Net Present Value of $22 102 after fifteen years.

Details of savings and costs are included in Appendices 3 and 4.

6.0 REALISATION OF SAVINGS

Savings may be realised by considering the accumulated savings from both the automatic Welding Positioner (see C.M.E. 63/2826 of 12th September, 1974) and the automatic Welding Manipulator. These two items enabling a reduction in cadre of 1 boilermaker for an activity level of 120 bogie wagon constructions per annum.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The above D.C.F. exercise has shown that purchase of an automatic Welding Manipulator is economically justifiable. The break even point occurs in approximately 5.1/2 years after initial purchase.

Purchase of this automatic Welding Manipulator is considered essential to improve the productivity of the Flanging Shop.

This proposal is therefore strongly recommended and C.E.P. form is attached in triplicate for approval please.

CHIEF MECHANICAL ENGINEER.

COPY FOR : PROJECTS ANDPLANNING

W.B. 26/9/74

APPENDIX 1

F/3

WAGON CONSTRUCTION PROGRAMMES FROM 1969/70 TO 1974/75

PERIOD	WAGON CLASS	NO OF WAGONS
1969/70	QUA	15
	VG	30
	XC	21
	WGX	50
	WK	2
	WSC	1
	WSW	1
	WVX	28
1970/71	Z	8
	ZS	2
	WBC	7
	QUA	75
	VG	10
	VH	47
	XC	20
	XR	1
	WGX	58
	WOA	39
1971/72	QUA	60
	VH	3
	XC	11
	XF	14
	WO	11
1972/73	XC	8
	XF	13
	XW	90
	WJL	2
1973/74	XF	4
	XFL	4
	WFX	23
	WVX	25
	WJP	4
1974/75 (as at 31.7.74)	WFX	22
	WFN	13
	WNA	12
	BNX	100
	WMX	10
	WOA	10
	VH	20
	WJP	9
	WJK	1
	Tankers for Golden Fleece	3

Total wagons constructed over 6 year period = 887
∴ average annual construction = 148

APPENDIX 2

F/4

Summary of wagons constructed and scheduled constructions for the period 1969/70 to 1974/75 (as at 31.7.74).

WAGON CLASS	NO. OF WAGONS.
XC	60
XF	31
XW	90
XFL	4
WGX	108
WO	11
WOA	49
QUA	150
WFX	45
WFN	13
VG	40
VH	70
WVX	53
WMX	10
BNX	100
XR	1
WJK	1
WK	2
WJL	2
WJP	13
WNA	12
TANKERS FOR GOLDEN FLEECE	3
WSC	1
WSW	1
Z	8
ZS	2
WBC	7
	TOTAL 887

A P P E N D I X 3

F/5

BASIS FOR MAN HOUR SAVINGS

1. The comparison of man hour savings has been made between using a welding Manipulator and the Bug 'O' unit for long weld runs. The tables below detail the welded lengths and times using the Manipulator and Bug 'O' and include the total weld times for completing the wagon.

In calculating welding times the following have been used:-

Welding Manipulator = 120ft./hr (36.6 m/hr).

Bug 'O' system = 75ft./hr (22.9 m/hr).

Remaining weld (combination of stick, wire feed and Bug 'O') = 15ft./hr (4.6 m/hr).

2. TABLE 1:- Length of weld by each machine. F/6

WAGON CLASS	NO OFF	LENGTH OF WELD PER WAGON (FT.)	TOTAL LENGTH OF WELD (FT.)	TOTAL LENGTH OF WELD MANIPULATOR (FT.)	TOTAL LENGTH OF WELD BUG 'O' (FT.)
XC	60	3 375	202 500	139 500	44 400
XW	90	5 000	450 000	50 400	50 400
XF	31	4 000	124 000	31 000	19 000
XFL	4	4 000	16 000	4 000	2 500
XR	1	5 900	5 900	3 000	3 000
WJK	1	5 900	5 900	3 600	3 600
WK	2	5 900	11 800	7 200	7 200
WJL	2	5 900	11 800	7 200	7 200
WJP	13	5 900	76 700	46 300	46 800
WNA	12	5 900	70 800	6 000	6 000
Tankers for Golden Fleece	3	5 900	17 700	10 800	10 800
WVX	53	4 200	222 600	30 210	30 210
WGX	108	4 200	453 600	61 560	61 560
QUA	150	3 000	450 000	79 500	79 500
VH	70	4 000	280 000	31 920	31 920
VG	40	3 500	140 000	16 000	16 000
WO	11	3 000	33 000	3 300	3 300
WOA	49	3 000	147 000	14 700	14 700
WFX	45	3 000	135 000	23 850	23 850
WFN	13	3 000	39 000	6 890	6 890
		Totals	2 893 300	577 430	468 830

3. TABLE 2 :- Time taken by each machine. F/7

WAGON CLASS	No. OFF	TIME TAKEN BY MANIPULATOR (HRS)	TIME FOR REMAINING WELD (HRS)	TIME TAKEN BY BUG 'O' (HRS)	TIME FOR REMAINING WELD (HRS)
XC	60	1 163	4 200	592	10 540
XW	90	420	26 640	672	26 640
XF	31	258	6 200	253	7 000
XFL	4	33	800	33	900
XR	1	25	193	40	193
WJK	1	30	153	48	153
WK	2	60	307	96	307
WJL	2	60	307	96	307
WJP	13	390	1 993	624	1 993
WNA	12	50	4 320	80	4 320
Tankers for Golden Fleece	3	90	460	144	460
WVX	53	252	12 826	403	12 826
WGX	108	513	26 136	821	26 136
OUA	150	663	24 700	1 060	24 700
VH	70	266	16 539	426	16 539
VG	40	133	8 267	213	8 267
WO	11	28	1 980	44	1 980
WOA	49	123	8 820	196	8 820
WFX	45	199	7 410	318	7 410
WFN	13	57	2 141	92	2 141
	TOTALS	4 813	154 392	6 251	161 632

F/8

4. Total time for welding including Manipulator for long runs (hrs). = 4813 + 154 392 = 159 205

Total time for welding including Bug 'O' for long runs =6251 + 161 632 = 167 883

Man hours saved over sample period (1969/70 to 1974/75) =8 678 hours.

Hence, average annual man hours saved (for 148 wagon constructions per annum) = $\frac{8\ 678}{6}$ hours

= <u>1 446 hours</u>

Average man hours saved for reduced activity level of 120 wagon constructions per annum. = $\frac{120 \times 1\ 446}{148}$ hours

= <u>1 173 hours</u>

F/10

A P P E N D I X 5

DISCOUNTED CASH FLOW ANALYSIS - BASED ON 120 BOGIE WAGON CONSTRUCTIONS PER ANNUM

YEAR	COST ($)	BENEFIT ($)	REMARKS	NET CASH FLOW ($)	P.V.F.	PRESENT VALUE (
1	22 000 150	 4 880	Capital cost of Welding Manipulator Maintenance costs. Labour saving.	- 17 270	1.0	- 17 27
2	150	 4 880	Maintenance costs Labour saving.	+ 4 730	.901	+ 4 26
3	150	4 880	As for Year 2	"	.840	+ 3 97
4	"	"	" " " "	"	.783	+ 3 70
5	"	"	" " " "	"	.730	+ 3 45
6	"	"	" " " "	"	.681	+ 3 22
7	"	"	" " " "	"	.635	+ 3 00
8	"	"	" " " "	"	.592	+ 2 80
9	"	"	" " " "	"	.552	+ 2 61
10	"	"	" " " "	"	.514	+ 2 43
11	"	"	" " " "	"	.480	+ 2 27
12	"	"	" " " "	"	.447	+ 2 11
13	"	"	" " " "	"	.417	+ 1 972
14	"	"	" " " "	"	.389	+ 1 84
15	"	"	" " " "	"	.363	+ 1 71

TOTAL NET PRESENT VALUE = +$22 102

F/9

A P P E N D I X 4

Annual Benefits

Man hours saved per year (120 wagon constructions) = 1 173 hours

Cost saving for 1 Boilermaker (@ $120.60 per week plus 38% contingency for Annual leave etc) = 1 173 x $4.16

= $4 880

Man hours available from 1 man, per annum. = 1 800 hours

Equivalent reduction of cadre = $\frac{1\ 173}{1\ 800}$ men

= 0.65 men

Maintenance Costs

The maintenance costs are slight and have been taken as approx. $150 per year.

Utilisation of Manipulator

The actual weld time will represent 2/3 or more of the utilised time of the Manipulator.

Utilised hours per annum = $1/6 \times \frac{4\ 813}{2/3}$ = 1 197 hours

$\therefore$ utilisation = $\frac{1\ 197}{1\ 800} \times \frac{100\%}{1}$ = 67%

APPENDIX G. G/1

HRS:SD
CMB. 63/2826.

3619.

13th January, 1975.

SECRETARY FOR RAILWAYS.

Midland Workshops - Welding Machines for Boiler and Flanging Shops.

1. PROPOSAL.

Purchase of 3 Semi-automatic Welding Machines for use in the Boiler and Flanging Shops.
Estimated Capital Cost = $10 025 (including Loan Incidentals).

2. FUTURE CONSTRUCTION PROGRAMME IN THE WORKSHOPS.

The future construction programme includes the following vehicles:-

10 WN Nickel Wagons
20 WOA Iron Ore Wagons
29 XE Ilmenite Wagons
3 JK Caustic Tankers
27 XF Alumina Wagons
7 XFL Lime Wagons
8 JPA Fuel Tank Cars

As shown above there is a heavy construction programme in the Workshops for both steel and aluminium wagons over the next twelve months. During this time at least three different wagon construction programmes will be progressing simultaneously in order to meet the rollingstock requirements for the respective projects. To enable this to be achieved at least three additional semi-automatic welding machines will be required.

3. BASIS OF JUSTIFICATION.

3.1 There are only two alternatives which can be considered. These are:-
A) Purchase of 3 Semi-automatic Welding Machines or
B) Hire of 3 Semi-automatic Welding Machines.

3.2 Alternative A.

At present the Workshops have two (2) 600 amp semi-automatic welding machines suitable for steel welding on hire to cope with the existing work load. Under Alternative A it is proposed that these two machines be purchased, the hire charges already paid being discounted from the purchase price of $3350 per machine. In addition it is proposed that a semi-automatic welding machine suitable for both aluminium and steel welding also be purchased. The machine under consideration is a SAF-MIG 600 amp welding machine at a cost of $4085. This machine is more costly as aluminium welding requires a more sophisticated unit.

3.3 Alternative B.

If the 3 welding machines are not purchased it will be necessary to continue hiring the two 600 amp welding machines until the

- 2 - G/2

end of December 1975 and an additional welding machine for aluminium welding will be required to be hired from the beginning of May until at least the end of January, 1976.

3.4 Full details of the costs involved in the two alternatives are shown at Appendix 1. i.e. Purchase cost of 3 machines = $10,025 (including load incidental), Hire cost of 3 machines = $10,410

Discounted Cash Flow Analysis.

A dis counted Cash Flow Analysis has not been carried out as it has been shown at Appendix 1 that the total payouts to hire the machines would exceed the purchase cost of the machines.

Recommendation.

It has been shown in this exercise that for the period under consideration the total payout to hire the machines exceeds the purchase price of the machines.

Purchase of these machines would mean that a total payout exceeding $10 000 for the hire of these machines without the workshops acquiring assets for future use would be avoided.

This proposal is therefore strongly recommended for the immediate purchase of the three machines. This action will obviate the necessity of continuing paying hire fees for welding machines which are essential to enable the rollingstock concerned to be constructed in accordance with the individual project requirements.

CHIEF MECHANICAL ENGINEER.

COPY FOR : PROJECTS AND PLANNING.

APPENDIX 1 G/3

Comparison of Costs for Hiring and Purchasing 3 Semi-Automatic Welding Machines

Alternative A.

At present two 600 amp semi-automatic welding machines suitable for welding steel are being hired at a cost of $60 per week. By purchasing these machines the first 8 weeks hire costs will be discounted from the purchase price and 10% of the hire cost thereafter.

Proportion of hire costs which can be discounted from the purchase price of $3350.

= 8 weeks at $60 per week = $480 per machine.

∴ Cost of machine = $3350 - $480 = $2870.

Purchase price of one SAF-MIG semi-automatic welding machine suitable for welding aluminium = $4085.

∴ Total cost of 3 Welding Machines = 2 x $2870 + 1 x$4085
= $9825 + 200 (loan incidentals)
= $10 025.

Alternative B.

For the future construction programme the 2 - 600 amp machines presently on hire would have to be hired from now to the end of December 1975 (a total of 51 weeks).

∴ Hire costs for 2 machines = 51 x 2 x $60 = $6120.

In addition a semi-automatic welding machine suitable for welding aluminium would have to be hired from the beginning of May 1975 to the end of January, 1976 (i.e. 39 weeks). The machine under consideration for purchasing is not for hire but a comparable machine has been quoted at $110 per week.

∴ Hire cost for 1 machine = 1 x 39 x 110 = 4290.

∴ Total Hire costs = $1620 + $4290 = $10 410.

SEC61/73

WESTERN AUSTRALIAN GOVERNMENT RAILWAYS

CAPITAL EXPENDITURE PROPOSAL G/4.

ORIGINATING BRANCH MECHANICAL

Number

Financial Year 1974/75

R. File No.

Branch File No. C.M.E. 63/2026

DESCRIPTION OF WORK Purchase of 3 Semi-automatic Welding Machines for the Boiler and Flanging Shops.

CLASSIFICATION OF EXPENDITURE: Function Wagon Construction

Reason Cost Reduction

SUMMARY OF JUSTIFICATION

The Workshops wagon construction programme for the next twelve months includes at least three different construction projects required to be processed simultaneously to enable the completion dates to be met. To achieve this three additional semi-automatic welding machines are required.

This exercise has compared the following alternatives:-

(a) Purchase of 3 Semi-automatic Welding Machines or

(b) Hire of 3 Semi-automatic Welding Machines (From Jan 75-Jan 76)

The cost of Alt (a) is $10 025 and Alt (b) is $10 410.

A D.C.F. Analysis has not been carried out as the total payout if the machines were to be hired exceeds the total cost of the machines. In addition by hiring the machines payouts in excess of $10 000 would be made without the Workshops gaining assets for future use.

ECONOMIC EVALUATION

Rate	Life	P.V. Costs $			P.V. Benefits $			Net P.V.
		Capital	C.R.F.	Total	Capital	C.R.F.	Total	
			NOT	APPLICA	BLE			$

CAPITAL REQUIRED

Branch	Source	This Year	Next Year	Future	Total
MECHANICAL		$10,025	$	$	$10,025

RECOMMENDED

CHIEF MECHANICAL ENGINEER.

14.1.1975

APPROVED IN PRINCIPLE

Commissioner of Railways

........19........

JH:KR

APPENDIX. H.

H/1

CME 63/2826

3619

12th September, 1974.

SECRETARY FOR RAILWAYS

Capital Works 1975/76 - Automatic Welding Positioner for Flanging Shop.

1. PROPOSAL

Purchase of a 5 ton Welding Positioner to improve Flanging Shop productivity.

Estimated Capital cost = $7 700

2. PRESENT SITUATION

The present situation has already been outlined in the previous D.C.F. exercise of 30th August, 1971 for an automatic Welding Positioner. The main points from the previous exercise are reiterated as follows:-

(i) It is considered essential that present welding facilities in the Workshops be urgently improved by the acquisition of automatic welding facilities.

(ii) Within the Workshops there are no automatic mechanical devices for positioning, consequently it is necessary to manoeuvre welding work either manually or by use of overhead cranes.

3. BENEFITS OF PROPOSAL

3.1 The benefits of this proposal have also been outlined in the previous exercise mentioned in (2) above. Summarising, the main benefits are as follows:-

(i) The workpiece may be manipulated into any convenient position for welding, within the limits of the machine.

(ii) Gravity weld is possible, which reduces operator fatigue and improves quality of the weld.

(iii) The Welding Positioner may be easily transported to any part of the shop.

(iv) Complex articles may be fabricated or repaired on the Welding Positioner.

3.2 The tangible savings have been derived and summarised in Appendices 1-4.

4. DETERMINATION OF WORKLOAD

4.1 The workload has been based on an activity level of 120 bogie wagon constructions per annum.

4.2 Savings have been determined based on specific items that have been manufactured on wagon constructions from 1969/70 to 1973/74 and the probable wagon issues for 1974/75.

H/2

4.3 It is assumed that the items used for justification, all of which are fairly common wagon structures, will be incorporated in similar form in future wagon construction programmes.

5. DISCOUNTED CASH FLOW EXERCISE

A Discounted Cash Flow Analysis has been carried out as per Appendix 6. This resulted in a Net Present Value of $17 102 after fifteen years.

Details of savings and costs are included in Appendices 3 - 5.

6. REALISATION OF SAVINGS

Savings may be realised by considering the accumulated savings from both the automatic Welding Positioner and the automatic Welding Manipulator (See CME 63/2926 of 13th September, 1974). These two items would enable a reduction in cadre of 1 boilermaker for an activity level of 120 bogie wagon constructions per annum.

7. CONCLUSIONS AND RECOMMENDATIONS

The above D.C.F. exercise has shown that purchase of an automatic Welding Positioner is economically justified. The break even point occurs in approximately 3.1/2 years after initial purchase.

Purchase of this automatic Welding Positioner is considered essential to improve the productivity of the Flanging Shop.

This proposal is therefore strongly recommended and C.E.P. form is attached in triplicate for approval please.

CHIEF MECHANICAL ENGINEER

APPENDIX 1

H/3

WAGON CONSTRUCTION PROGRAMMES FROM 1969/70 TO 1974/75

PERIOD	WAGON CLASS	NO OF WAGONS
1969/70	QUA	15
	VG	30
	XC	21
	WGX	50
	WK	2
	WSC	1
	WSW	1
	WVX	28
1970/71	Z	8
	ZS	2
	WBC	7
	QUA	75
	VG	10
	VH	47
	XC	20
	XR	1
	WGX	58
	WOA	39
1971/72	QUA	60
	VH	3
	XC	11
	XF	14
	WO	11
1972/73	XC	8
	XF	13
	XW	90
	WJL	2
1973/74	XF	4
	XFL	4
	WFX	23
	WVX	25
	WJP	4
1974/75 (as at 31.7.74)	WFX	22
	WFN	13
	WNA	12
	BNX	100
	WMX	10
	WOA	10
	VH	20
	WJP	9
	WJK	1
	Tankers for Golden Fleece	3

Total wagons constructed over 6 year period = 887
∴ average annual construction = 148

APPENDIX 2

H/4

Summary of wagons constructed and scheduled constructions for the period 1969/70 to 1974/75 (as at 31.7.74).

WAGON CLASS	NO. OF WAGONS.
XC	60
XF	31
XW	90
XFL	4
WGX	108
WO	11
WOA	49
QUA	150
WFX	45
WFN	13
VG	40
VH	70
WVX	53
WMX	10
BNX	100
XR	1
WJK	1
WK	2
WJL	2
WJP	13
WNA	12
TANKERS FOR GOLDEN FLEECE	3
WSC	1
WSW	1
Z	8
ZS	2
WBC	7
	TOTAL 887

APPENDIX 3

DETERMINATION OF SAVINGS OVER 6 YEAR PERIOD.

H/5

1. Shear plate Assembly.

WAGON CLASS	WELD AND SET-UP TIME PRESENT METHODS (HRS)	WELD AND SET-UP TIME WITH "POSITIONER" (HRS)	TIME SAVED PER WAGON (HRS)	NO. OF WAGONS	TOTAL TIME SAVED. (HRS)
XC	16	12	4	60	240
XF	16	12	4	31	124
XW	16	12	4	90	360
XFL	16	12	4	4	16
WNA	16	12	4	12	48
				TOTAL	788

Work requires continuous attendance of 1 boilermaker.

∴ Man hours saved = 788 hours.

"Positioner" utilisation = 2 364 hours.

2. Bolster Sub Assembly.

WAGON CLASS	WELD AND SET-UP TIME PRESENT METHODS (HRS)	WELD AND SET-UP TIME WITH "POSITIONER" (HRS)	TIME SAVED PER WAGON (HRS)	NO. OF WAGONS	TOTAL TIME SAVED. (HRS)
BMX	8	6	2	100	200
WMX	8	6	2	10	20
WFX	8	6	2	45	90
WGX	8	6	2	108	216
WVX	8	6	2	53	106
QUA	8	6	2	150	300
VH	8	6	2	70	140
WO	8	6	2	11	22
WOA	8	6	2	49	98
				TOTAL	1 192

Work requires continuous attendance of 1 boilermaker.

∴ man hours saved = 1 192 hours

"Positioner" utilisation = 3 575 hours.

3. Stub Sill Final Assembly

H/6

WAGON CLASS	WELD AND SET-UP TIME PRESENT METHOD (HRS)	WELD AND SET-UP TIME WITH "POSITIONER" (HRS)	TIME SAVED PER WAGON (HRS)	NO. OF WAGONS	TOTAL TIME SAVED (HRS)
XR	12	10.1/2	1.1/2	1	1.1/2
WJK	12	10.1/2	1.1/2	1	1.1/2
WK	12	10.1/2	1.1/2	2	3
WJL	12	10.1/2	1.1/2	2	3
WJP	12	10.1/2	1.1/2	13	19.1/2
WNA	12	10.1/2	1.1/2	12	18
Tankers for Golden Fleece.	12	10.1/2	1.1/2	3	7.1/2
				Total	54

Work requires continuous attendance of 1 boilermaker.

∴ man hours saved = 54 hours

"Positioner" utilisation = 378 hours.

4. Final Welding of Complete Centre Sill

WAGON CLASS	WELD AND SET-UP TIME PRESENT METHOD (HRS)	WELD AND SET-UP TIME WITH "POSITIONER" (HRS)	TIME SAVED PER WAGON (HRS)	NO. OF WAGONS	TOTAL TIME SAVED (HRS)
BNX	15	12.0	3.0	100	300.0
WMX	15	12.0	3.0	10	30.0
WGX	12	9.6	2.4	108	259.2
WVX	12	9.6	2.4	53	127.2
WFX	12	9.6	2.4	45	108.0
QUA	8	6.4	1.6	150	240.0
VH	8	6.4	1.6	70	112.0
	12	9.6	2.4	11	26.4
WOA	12	9.6	2.4	49	117.6
				Total	1320

Work requires continuous attendance of 1 boilermaker

∴ man hours saved = 1 320 hours

"Positioner" utilisation = 5 280 hours

H/7

5. Pressed Ends for any Tanker type Construction.

WAGON CLASS	WELD AND SET-UP TIME PRESENT METHODS (HRS)	WELD AND SET-UP TIME WITH "POSITIONER" (HRS)	TIME SAVED PER WAGON (HRS)	NO. OF WAGONS	TOTAL TIME SAVED. (HRS)
XR	80	60	20	1	20
WJK	120	90	30	1	30
WK	80	60	20	2	40
WJL	80	60	20	2	40
WJP	120	90	30	13	390
WNA	40	30	10	12	120
TANKERS FOR GOLDEN FLEECE	80	60	20	3	60
				TOTAL	700

Work requires continuous attendance of 2 boilermakers and 1 apprentice boilermaker.

∴ man hours saved = 1 400 hours for boilermaker.
+ 700 hours for apprentice.

"Positioner utilisation" = 2 100 hours.

H/8

6. Summary of Savings and Utilisation

	"Positioner" Utilisation (hours)	Boilermakers Time Saving (hours)
	2 364	788
	3 575	1 192
	378	54
	5 280	1 320
	2 100	1 400
Totals	13 697 hours	4 754

Hence average annual utilisation = $\frac{13\,697}{6}$ hrs = 2 283 hrs
(for 148 wagons per annum)

And average annual man hour savings = $\frac{4\,754}{6}$ boilermakers + $\frac{700}{6}$ app
(for 148 wagons per annum)

= 792 boilermaker hours
+ 117 hours 3rd year apprentice.

Savings

Boilermaker @ \$120.60 per week = $\frac{\$120.60 \times 792}{40}$ = \$2 388

3rd year App @ \$63.71 per week = $\frac{\$63.71 \times 117}{40}$ = 186

Direct Labour Total = \$2 574

Add 38% contingency for Annual leave, sick leave, etc. = 978

Total saving (for 148 wagons) = \$3 552

APPENDIX 4. H/9

Savings and Utilisation for Various Activity Levels.

1. For 148 Wagon Constructions per Annum.

"Positioner" Utilisation = 2 283 hours

Labour saving = $3 552

2. For 120 Wagon Constructions per Annum.

"Positioner Utilisation $= \frac{120}{148} \times 2283$ hrs. = 1 851 hrs.

Labour saving $= \frac{120}{148} \times \$3\ 552$ = $2 880

3. For 100 Wagon Constructions per Annum.

"Positioner" Utilisation $= \frac{100}{148} \times 2\ 283$ hrs = 1 543 hrs.

Labour saving. $= \frac{100}{148} \times \$3\ 552$ = $2 460

APPENDIX 5. H/10

Estimated Fixed Annual Operating Costs.

1. Annual Maintenance Cost.

Based on attendance of maintenance fitter for 1/2 day once per month.

i.e. 4 hours per month.

∴ total time on maintenance = 12 months x 4 hours/month.
= 48 hours.

Labour cost @ 120.60 per week $= \frac{\$120.60 \times 48}{40} = \$145$

+ 38% contingency for sick leave, annual leave etc. = $55

Total = $200

2. Annual Estimated Electrical Costs.

Based on full motor power consumption for 25% of the utilised time and electricity cost of $0.02 per kw hour.

Total drive motor horse power (Max) = 5 h.p.

Utilised hours per annum (Max) = 2 300 hours.

∴ Electrical cost =
2 hp x 0.746 kw/hp x 2 300 hrs x 25% x $0.02/kw hr.
= $17.09 say $20.

H/11

APPENDIX 6

DISCOUNTED CASH FLOW ANALYSIS - BASED ON 120 BOGIE WAGON CONSTRUCTIONS PER ANNUM

YEAR	COST $	BENEFIT $	REMARKS	NET CASH FLOW $	P.V.F.	PRESENT VALUE $
1	7 700		Capital Cost of "Welding Positioner"	- 5 040	1.0	- 5 040
	200		Estimated annual maintenance cost.			
	20		Estimated annual electrical cost.			
		2 880	Labour saving.			
2	200		Maintenance Costs.	+ 2 660	.901	+ 2 397
	20		Electrical Costs.			
		2 880	Labour saving.			
3	220	2 880	As for year 2.	+ 2 660	.840	+ 2 234
4	"	"	" " " "	"	.783	+ 2 083 Break even.
5	"	"	" " " "	"	.730	+ 1 942
6	"	"	" " " "	"	.681	+ 1 811
7	"	"	" " " "	"	.635	+ 1 689
8	"	"	" " " "	"	.592	+ 1 575
9	"	"	" " " "	"	.552	+ 1 468
10	"	"	" " " "	"	.514	+ 1 367
11	"	"	" " " "	"	.480	+ 1 277
12	"	"	" " " "	"	.447	+ 1 189
13	"	"	" " " "	"	.417	+ 1 109
14	"	"	" " " "	"	.389	+ 1 035
15	"	"	" " " "	"	.363	+ 966

TOTAL NET PRESENT VALUE = + $17 102

APPENDIX. J.

J/1

HS:KR

CME 67/2682

3619

1st May, 1974.

SECRETARY FOR RAILWAYS

Midland Workshops - Welding Machine for Boiler and Flanging Shops.

1. PROPOSAL

Purchase of a 600 amp Push Pull M.I.G. Welding Machine for use in the Boiler and Flanging Shops.

Capital Cost = $4 600 (including Loan Incidentals)

2. PRESENT SITUATION

The welding machines at present in use in the Boiler and Flanging Shops have a maximum range of welding from the power source of 4m. This means that with the repair or construction of tanker type vehicles, the welding machines have to be dismantled and re-assembled inside the tankers to enable the internal welds to be done. After completion of the internal welds the welding machines are again dismantled, taken out of the tanker and re-assembled.

While the internal welds are being done inside the tanker considerable time is spent in manouvering the welding machine each time a new welding position is required.

3. ADVANTAGES OF PROPOSAL

The Push Pull M.I.G. Welding Machine has a range of welding of 20m from the welding machine. This means that welding can be done inside a tanker type vehicle with ease while the welding machine remains outside the tanker.

Once inside the tanker the welding range of 20m from the power source allows easy access to all points which require welding.

The proposed welding machine has been on trial in the Workshops for the last 4 weeks and is satisfactory in all aspects.

4. COST SAVINGS

Details of the cost savings which will accrue are shown in Appendix I.

5. DISCOUNTED CASH FLOW EXERCISE

A D.C.F. exercise has been carried out and is shown in Appendix II. This resulted in a Net Present Value of +$3 548 after 10 years.

J/2

- 2 -

6. RECOMMENDATION

The Discounted Cash Flow Analysis with a Total Net Present Value of +$3 548 after 10 years has shown that the purchase of the proposed machine will result in a cost saving. The break even point occurs in Year 2.

The use of this machine will improve efficiency in construction and repair work. It would also result in less time off traffic for damaged vehicles with commensurate greater earning capacity for the department.

7. SOURCE OF FUNDS

Funds are available from R.M.A.D.F.S.A. and if approved an A.F.E. will be submitted for early purchase from that account.

For your approval, please.

CHIEF MECHANICAL ENGINEER

COPY FOR: PROJECTS AND PLANNING

J/3

APPENDIX I

COST SAVINGS

1. WORK LOAD

The work load used in this exercise has been taken for the first 3 years from the forecast program of future projects to go through the Workshops. The types of wagons shown are the ones to which the use of the proposed welding machine will be of most benefit.

1.1 These are as follows:-

1974/75

Construction of 12 Nickel Wagons

Repairs to 4 tanker damaged in a recent derailment.

Modifications to 4 privately manufactured rail tankers.

1.2 1975/76

Construction of 34 Alumina Wagons.

Construction of 20 Wheat Wagons.

Construction of 3 Caustic Tankers.

Modifications to 3 privately manufactured rail tankers.

1.3 1976/77

Modifications to 3 privately manufactured rail tankers.

1.4 As can be seen from Appendix II, the forecast work load for 1974/77 will give a net present value of +$1293 after 3 years. As there has been no forecast work load for the years after 1976/77 it has been assumed for the purposes of this exercise that there will be an estimated savings of at least $500 per year after 1976/77 due to construction, repairs, modifications etc.

2. The time to dismantle the existing welding machines and re-assemble inside the tanker and then to dismantle and take the machine outside again is as follows:-

Time Per welding machine = 16 hours

∴ Avoided costs = 16 hrs for a tradesman at 2.53 per hr = $40.48
16 hrs for an apprentice at 1.81 per hr = $28.96
Total = $68.44

The above saving only applies in this instance to the construction of Nickel wagons, caustic tankers and to the repairs and modifications to rail tankers.

3. The following times would be saved due to the ease with which the welder could reposition himself for different internal welds once within the wagon or tanker:-

Nickel wagons	= 20 hrs per wagon
Alumina wagons	= 11 hrs per wagon
Caustic tankers	= 20 hrs per tanker
Modifications to tankers	= 20 hrs per tanker
Wheat wagons	= 11 hrs per wagon.

- 2 -

J/4

4. TOTAL COST SAVINGS FOR USE IN D.C.F. EXERCISE

4.1 1974/75

Construction of 12 Nickel Wagons

Avoided cost of having to dismantle and reassemble a welding machine = 12 x $68.44 = $821.28.

Cost saving due to ease of welding within wagon = 12 x 20hrs x 2.53 (tradesman's rate/hr) = $607.20.

Total saving = ($821.28 x $607.20) x 1.30 (allowance for leave etc.) = $1 857.00.

Repairs to 4 tankers damaged in recent derailment

Avoided cost of having to dismantle and reassemble a welding machine = 4 x $68.44 = $273.76.

Total saving = $273.76 x 1.30 (allowance for leave etc.) = $356.00

Modifications to 4 privately manufactured rail tankers

Avoided cost of having to dismantle and reassemble a welding machine = 4 x $68.44 = $273.76.

Cost saving due to ease of welding within tanker = 4 x 20hrs x 2.53 (tradesman's rate per hr) = $202.40.

Total saving = ($273.76 + $202.40) x 1.30 = $619.00.

Total saving for 1974/75 = $1 857 + $356 + $619 = $2 832.

4.2 1975/76

Construction of 34 Alumina Wagons

Cost saving due to ease of welding within wagon = 34 x 11 x 2.53 = $946.22.

Total saving = $946.22 x 1.30 =$1230.00.

Construction of 20 Wheat Wagons

Cost saving due to ease of welding within wagon = 20 x 11 x 2.53 = $556.60.

Total saving = $556.60 x 1.30 = $724.00.

Construction of 3 Caustic Tankers

Avoided cost of having to dismantle and reassemble a welding machine = 3 x $68.44 = $205.32.

Cost saving due to ease of welding within wagon = 3 x 20 x 2.53 = $151.80.

Total savings = ($205.32 + $151.80) x 1.30 = $464.00.

Modifications to 3 privately manufactured rail tankers

Avoided cost of having to dismantle and reassemble a welding machine = 3 x $68.44 = $205.32.

Cost saving due to ease of welding within tanker = 3 x 20 x 2.53 = $151.80.

Total saving = ($205.32 + $151.80) x 1.30 = $464.00.

Saving for 1975/76 = $1230+ $724 + $464 + $464 = $2 882.

4.3 1976/77

Modifications to 3 privately manufactured rail tankers

Avoided cost of having to dismantle and reassemble a welding machine = 5 x $68.44 = $205.32.

Cost saving due to ease of welding within tanker = 2 x 20 x 2.53 = $151.80

Saving = ($205.32 + $151.80) x 1.30 = $464.00.

Total Saving = $464 + $100 (allowance for repairs) = $564.00.

Savings for 1976/77 = $564.00.

2.4 1977 Onwards

An estimated saving of least $500 per year due to construction, modifications, repairs, etc.

APPENDIX II

DISCOUNTED CASH FLOW ANALYSIS

YEAR	DESCRIPTION	COST $	CASH FLOW $	P.V. FACTOR	PRESENT VALUE $
1	Capital Cost of Welding Machine	- 4 600			
	• Cost savings due to:-				
	Construction of 12 Nickel Wagons	+ 1 857	- 1 768	1	- 1 768
	Repairs to 4 Damaged Tankers	+ 356			
	Mods. to 4 privately manufactured tankers	+ 619			
2	• Cost savings due to:-				
	Construction of 34 Alumina Wgns	+1 230	+ 2 882	.901	+ 2 597
	Construction of 20 Wheat Wgns	+ 724			
	Construction of 3 Caustic Tankers	+ 464			
	Mods. to 3 privately manufactured tankers.	+ 464			
3	• Cost savings due to mods. to 3 privately manufactured tankers	+ 564	+ 564	.840	+ 474
4	Cost saving due to repairs, mods etc.	+ 500	+ 500	.783	+ 392
5	As for Year 4	+ 500	+ 500	.730	+ 365
6	" " " "	+ 500	+ 500	.681	+ 341
7	" " " "	+ 500	+ 500	.635	+ 318
8	" " " "	+ 500	+ 500	.592	+ 296
9	" " " "	+ 500	+ 500	.552	+ 276
10	" " " "	+ 500	+ 500	.514	+ 257
	Total Net Present Value				+ 3 548

• Details shown in Appendix I.

SECTION 16.

WAGON DESCRIPTIONS.

For purposes of comparison three all-steel wagons were chosen as datums and indicated as such in Section 4 "Comparative Tare Weights".

These were the wagon classes :-

"WW" Standard Gauge Wheat Hopper Wagon, manufactured by A.E. Goodwin, Sydney, New South Wales.

"WST" Standard Gauge Tank Wagon, manufactured by A.E. Goodwin, Sydney, New South Wales.

"JTE" Narrow Gauge Tank Wagon, built for B.P. Australia Ltd. by Commonwealth Engineering.

The remaining descriptions are self explanatory -

Details of the remaining Aluminium Wagons are available from the Outline drawings at Section 17.

WAGON DESCRIPTION

RAIL TANK CAR CLASS JTE

This wagon has been designed for the transport of petroleum products on either narrow or standard gauge.

The design utilises the tank as the underframe of the wagon, and brakegear etc., is mounted on brackets welded to the tank. One feature of the design is that a change of bogies, brake gear and drawgear enables it to be used on the standard gauge system.

It has three compartments of 16 365 litres, 15 911 litres and 16 365 litres respectively giving a total capacity of 81 371 litres for use on standard gauge. With the centre compartment blanked off, the capacity is 65 460 litres for use on narrow gauge lines.

WHEAT HOPPER WAGON CLASS WW

The wheat hopper wagon, of all steel construction was commissioned for the transport of grain from the country wheat belt grain storage depots along the standard gauge route to the sea side storage facilities of C.B.H.

The hoppers are of tear drop section. Filling is achieved through a continuous hatch and emptied through four air operated discharge doors. A catwalk is positioned at one side of the hatch and extends over each end to allow an operator to pass from one vehicle to another.

CLASS WST

A rail tank car of all steel, monocoque construction was commissioned mainly to meet departmental demands for fuel transport to diesel depots.

The tank shell has a capacity of 78 193 litres, filling being achieved through pipes with apertures located on the top of the tank. Unloading is done via two 100 mm outlet valves positioned at the bottom of the tank shell with connections to both sides of the rail tank car.

Fitted with four safety valves, the rail tank car is suitable for the transport of motor spirit and distillate and can be used for the transport of furnace oil by removing the safety valves and fitting safety vents.

GENERAL DATA

	CLASS JTE	CLASS WW	CLASS WST
Owner	B.P. Australia Ltd.	Westrail	Westrail
Designer	*Commonwealth Engineering	A.E. Goodwin Ltd, Sydney	A.E. Goodwin Ltd.
Manufacturer	* " "	Scotts, Ipswich, Qld.	" " "
Commissioned	8th November, 1965	October, 1966	26th October, 1970
Rail Gauge	1 067 mm	1 435 mm	1 435 mm
Length over strikers		13 195	17 646
" over end sills	16 116	12 979	17 430
" over pulling faces of coupler	16 954	13 883	18 334
Bogie Centres	12 420	10 173	14 325
Maximum width		3 200	2 870
Maximum height (tare)	3 480	4 572	4 200
Deck/Floor Height (tare)	1 000	1 070	1 115
Capacity		89.2 m^3	78.2m^3
Bogies	Cast steel A3 type 10" x 5" journal	Ride Control inside brakes	Wabcopac Brake Unit
Brake System	Vacuum	Westinghouse ABSD	Air - Davies Metcalfe
Hand Brake	W.A.G.R. Ratchet & Pawl	Miner D-3290-XL	Miner D-3290-XL
Weight - Tare	24.8 t	25.0 t	30.9 t
" - Loaded (Gross)	54.8 t	95.25 t	95.25 t
Coupler	W.A.G.R. Improved yoke		Type E, 10A Contour
Others - Load (0.92 SG)	32 731		

* Designed under licence to Union Tank Car Co.

NOTE: Of all steel construction, the above three wagons have been chosen as datums in this treatise.

WAGON DESCRIPTION

WAGON CLASS XBC

This wagon was specially designed to haul bauxite from Jarrahdale in the Darling Range to Kwinana. It is of composite construction in that the underframe is manufactured from steel plate and the hopper from aluminium alloy.

The wagon hopper is of the divided type and is provided with bottom discharge doors which are operated by compressed air working on the over centre principle. It is of the self cleaning type and in this respect considerable research was undertaken to obtain the optimum slope of side sheeting to ensure complete discharge of bauxite.

GENERAL DATA

Owner	Westrail
Designer	Westrail
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	July, 1963
Rail Gauge	1 067
Length over end sills	12 598
" over pulling faces of coupler	13 436
Bogie Centres	9 906
Maximum width	2 895
Maximum height (Loaded)	2 971
Deck/Floor Height (Loaded)	1 080
Capacity	42.5 m^3
Bogies	Buckeye Cushion Ride 11" x 6"
Brake System	Air, Westinghouse ABDEL
Hand Brake	Ellcon high powered
Coupler	Type E 10A Contour Automatic
Weight - Tare	22.1 t
" - Gross Load	83 t
Others - Discharge time	4-6 seconds

WAGON DESCRIPTION

WAGON CLASS XC

This wagon was designed to haul bauxite from Jarrahdale in the Darling Ranges to Kwinana. It is of a monocoque design constructed entirely of aluminium alloy.

Two large bottom discharge doors are operated by air cylinders through an over centre linkage. These in conjunction with generous angles of slope and side sheets allow the wagon to discharge the load quickly and cleanly.

GENERAL DATA

Owner	Westrail
Designer	Westrail
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	August, 1968
Rail Gauge	1 067
Length over end sills	12 598
" over pulling faces of coupler	13 436
Bogie Centres	9 677
Maximum width	2 895
" height (Loaded)	3 124
Deck/Floor Height	1 080
Capacity	47.96 m^3
Bogies	Auscopac
Brake System	Air, Westinghouse
Hand Brake	Ellcon high powered
Coupler	Type E 10A Contour Automatic
Weight - Tare	17.3 t
" - Load (Gross)	81.3 t
Discharge time	4 seconds

WAGON DESCRIPTION
BULK CEMENT TANKER WAGON CLASS XR

This all aluminium bulk cement tanker wagon has been designed to transport cement from the Manufacturers in the Metropolitan area to bulk handling installations at country depots.

The wagon is comprised of a two compartment tank suspended at each end by an integrally formed sub frame providing for the housing of the drawgear and mounting of the bogies and brake gear. Each of the two compartments is fitted with two filling hatches (weather proof), safety valve, pressure gauge, and 100 mm feed cone for the aerated discharge of cement.

An overhead loading system is used for filling this wagon by gravitational feed. Unloading is effected by the use of compressed air supplied from a blower unit, at a working pressure of 60-80 kPa with a maximum of 100 kPa. From a regulating valve on each side of the wagon, 15 mm pipes are connected to each compartment, which aerates and pressurises the cement, and a 38 mm pipe take-off supplies air to the feed cone from which the cement is drawn. The discharge is through a 100 mm cam lock connection adjacent to the feed cone, to which is connected a flexible hose at the unloading depot. Discharge is controlled by a valve which regulates the ratio of cement and air entering the discharge-line. The discharge is at the rate of approximately 20 tonnes per hour when feeding into an overhead silo 15 m above rail.

Side ladders and cat walk are fitted to allow access to filling hatches.

GENERAL DATA

Owner	Westrail
Designer	Westrail
Manufacturer	Westrail Workshops, Midland W.A.
Commissioned	October, 1968
Rail Gauge	1 067
Length over end sills	14 363
" over pulling faces of coupler	15 201
Bogie Centres	10 669
Maximum width	2 540
" height (loaded)	3 229
Capacity	38.3 m^3
Bogies	Ride Control
Braking system	Vacuum 21" 'F' type cylinder(2)
Handbrake	Miner D-3290-XL
Coupler	Jones type buffer with Miner draft gear package
Weight - Tare	15.2 t
" - Loaded	60.9 t

WAGON DESCRIPTION

WAGON CLASS XF

This wagon has been designed to haul Alumina from the bauxite refinery on location in the Darling Scarp to Kwinana the industrial sea loading port. The wagon is constructed entirely from welded aluminium alloy. The aluminium alloys utilised in its construction comply with the Aluminium Association of America Specifications viz alloy 5083 for plate and 6061 T6 for extrusions.

Filling is achieved through five circular roof hatches. The top openings are closed to weather by individual hatch covers constructed from reinforced fibre glass mounted on rollers and connected together. Discharge is achieved through six openings in the bottom of the wagon. The bottom door is a single plate mounted on steel rollers for ease of operation and is traversed longitudinally by a rack and pinion mechanism activated by an air motor at the discharge site.

The vehicle is fitted with a catwalk, which allows workmen to pass from one vehicle to another to open and close the roof hatches.

GENERAL DATA

Owner	Westrail
Designer	Westrail
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	December, 1971
Rail Gauge	1 067
Length over Strikers	15 000
" over End Sills	14 452
" over pulling faces of coupler	15 469
Bogie Centres	11 582
Maximum width	2 870
" height (Loaded)	3 851
Capacity	69.4 m^3
Bogies	Auscopac
Braking System	Air, Westinghouse ABDEL
Hand Brake	Miner D-3290-XL
Coupler	F type 10A Contour Automatic
Weight - Tare	18.36 tonnes
" - Loaded Gross	81.3 tonnes

WAGON DESCRIPTION

WAGON CLASS XFL

This wagon has been designed to haul lime to the bauxite refinery on location in the Darling Scarp. The wagon is constructed entirely from welded aluminium alloy. The aluminium alloys utilised in its construction comply with the Aluminium Association of America Specifications viz alloy 5083 for plate and 6061 T6 for extrusions.

Filling is achieved through five circular roof hatches. The top openings are closed to the weather by individual hatch covers constructed from reinforced fibre glass, mounted on rollers and connected together.

Discharge is achieved through six openings in the bottom of the wagon, each opening is provided with an individually operated door.

The vehicle is fitted with a catwalk which allows workmen to pass from one vehicle to another to open and close the top hatches.

GENERAL DATA

Owner	Westrail
Designer	Westrail
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	January, 1974
Rail Gauge	1 067
Length over strikers	15 000
" over end sills	14 452
" over pulling faces of coupler	15 469
Bogie Centres	11 582
Maximum width	2 870
Maximum height	3 851
Capacity	69.4 m^3
Bogies	Auscopac
Braking system	Air, Westinghouse ABDEL
Handbrake	Miner D-3290-XL
Coupler	Type F 10A Contour Automatic
Weight - Tare	17.8 t
- Loaded (Gross)	72.3 t

WAGON DESCRIPTION

RAIL TANK CAR CLASS JPA

This rail tank car has been designed to transport furnace oil between Kwinana and Pinjarra for Alcoa of Australia Ltd.

It is an all welded aluminium alloy rail tank car comprising a dropped centre cylindrical tank with semi-ellipsoidal heads, suspended at each end by an integrally formed stub sill and bolster assembly.

The tank is filled by means of two fill pipes located on the top of the tank shell, whilst unloading is done via two 100 mm outlet valves positioned at the bottom of the tank shell which feed single 150 mm outlet pipe connections on either side of the rail tank car.

GENERAL DATA

Owner	Alcoa of Australia
Designer	* Westrail
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	January, 1976
Rail Gauge	1 067
Length over end sills	17 100
" over pulling faces of coupler	18 118
Bogie Centres	13 982
Maximum width	2 895
Maximum height (Loaded)	4 420
Deck/Floor height (Loaded)	940
Capacity (Max.)	83 m^3
Bogies	11" x 6" Auscopac ride control
Brake System	Air, Westinghouse ABD
Handbrake	Miner D-3290-XL
Coupler	F type 10A Contour, automatic
Weight - tare	19.3 t
- loaded (Gross)	78.3 t
Others - Load - Fuel oil (0.995 SG)	59 296 ℓ
Capacity (Max.)	83 080 ℓ

* Designed under licence to the General American Transportation Corporation.

WAGON DESCRIPTION

BULK CEMENT TANKER WAGON CLASS WK

This all aluminium bulk cement tanker wagon, the largest of its type in the Southern Hemisphere, has been designed to transport cement from the Manufacturers in the Metropolitan area to bulk handling installations at country depots.

The wagon is comprised of a two compartment tank suspended at each end by an integrally formed sub frame providing for the housing of the drawgear and mounting of the bogies and brake gear. Each of the two compartments is fitted with two filling hatches (weather proof), safety valve, pressure gauge and 100 mm feed cone for the aerated discharge of cement.

An overhead loading system is used for filling this wagon by gravitational feed. Unloading is effected by the use of compressed air supplied from a blower unit, at a working pressure of 100 kPa with a maximum of 200 kPa. From a regulating valve on each side of the wagon, 75 mm pipes are connected to each compartment, which aerates and pressurises the cement, and a 38 mm pipe take-off supplies air to the feed cone from which the cement is drawn. The discharge is through a 100 mm cam lock connection adjacent to the feed cone, to which is connected a flexible hose at the unloading depot. Discharge is controlled by a valve which regulates the ratio of cement and air entering the discharge-line. The discharge is at the rate of approximately 15 tonne per hour when feeding a distance of 21 m horizontally into an overhead silo 15 m above rail.

GENERAL DATA

Owner	Westrail
Designer	Westrail
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	March, 1970
Rail Gauge	1 435
Length over Strikers	19 227
" over end sills	19 024
" over pulling faces of coupler	19 913
Bogie Centres	16 154
Maximum Width	3 073
Maximum height (tare)	4 013
Deck/Floor height (tare)	1 082
Capacity	71.4 m^3
Bogies	Wabcopac
Brake System	Air, Westinghouse ABSD
Handbrake	Miner D-3290-XL
Coupler	Type E 10A Contour Automatic
Weight - Tare	23.3 t
" - Loaded (Gross)	95.25 t

WAGON DESCRIPTION
WHEAT HOPPER WAGON CLASS WWA

This all aluminium wagon is used for the haulage of bulk grain wheat from Merredin in the wheat belt to North Fremantle on the coast, a distance of some 200 route miles.

The wagon is of all welded aluminium alloy construction using plate in 5083 aluminium alloy and extruded sections in 6061 aluminium alloy. All welding of aluminium is by the metal inert gas (M.I.G.) process.

The strength of the wagon structure has been designed to conform with the requirements of the Association of American Railroad Specification for Design Fabrication and Construction of Freight Cars.

Loading is via a continuous opening in the top of the wagon. This opening is closed to weather by 5 hatch covers constructed in reinforced fibre glass, hinged along one side of the hopper. Unloading is effected through four bottom discharge doors which slide horizontally on nylon guides. All doors are operated simultaneously by a portable air motor which can be applied to a rack and pinion device, accessible from either side of the wagon.

GENERAL DATA

Owner	Westrail
Designer	Westrail
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	January, 1969
Rail Gauge	1 435
Length over strikers	15 416
" over pulling faces of coupler	16 104
Bogie Centres	12 344
Maximum width	3 200
Maximum height (tare)	4 496
Capacity	97.4 m^3
Bogies	Wabcopac
Brake System	Air, Westinghouse WF2
Hand Brake	Miner D-3290-XL
Coupler	Type E 10A Contour Automatic
Weight - Tare	19.4 t
" - Loaded (Gross)	95.25 t

WAGON DESCRIPTION

RAIL TANK CAR CLASS JGE

This vehicle is for the transportation of Petroleum products from Kewdale to country depots.

This vehicle has been designed with two separate compartments thus enabling the oil company concerned to carry a combination of products at any one time.

Filling is achieved through pipes with apertures located on the top of the tank shell, whilst unloading is carried out via outlet valves positioned at the bottom of the tank shell with piped connections to either side of the rail tank car.

GENERAL DATA

Owner	H.C. Sleigh (Golden Fleece)
Designer	Westrail.*
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	October, 1975
Rail Gauge	1 067
Length over end sills	20 300
" over pulling faces of coupler	21 304
Bogie Centres	16 600
Maximum width	2 660
Maximum height (Loaded)	3 330
Capacity	66.24 m^3
Bogies	9" x 5" Conventional lever
Braking System	Vacuum
Handbrake	Miner D-3290-XL
Coupler	Improved Yoke
Weight - Tare	18.2 t
- Loaded (Gross)	64 t
Others - Load - Distillate (0.76 SG)	60 263 ℓ
- Fuel Oil (0.85 SG)	53 882 ℓ
Max. capacity	66 238 ℓ

* Designed under licence to the General American Transportation Corporation.

WAGON DESCRIPTION

RAIL TANK CAR CLASS WJP

This vehicle is for the transportation of petroleum products from Kewdale to Country Depots.

It is an all welded aluminium alloy rail tank car, comprising a dropped centre cylindrical tank with semi-ellipsoidal heads, suspended at each end by an integrally formed stub sill and bolster assembly.

The single compartment is filled via two fill pipes located on the top of the tank shell whilst unloading is via two 100 mm outlet valves positioned at the bottom of the tank.

GENERAL DATA

Owner	Shell Oil Company of Australia Ltd.
Designer	Westrail *
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	May, 1974
Rail Gauge	1 435
Length over end sills	17 100
" over pulling faces of coupler	18 118
Bogie Centres	13 982
Maximum width	3 200
Maximum height (tare)	4 114
Capacity	83.9 m^3
Bogies	Wabcopac 11" x 6" Journal
Braking System	Air, Westinghouse ABSD
Handbrake	Miner D-3290-XL
Coupler	F type 10A Contour Automatic
Weight - Tare	20.73 t
- Loaded (Gross)	82 t
Others - Load - Distillate (0.76 SG)	80 662 ℓ
- Motor spirit (0.85 SG)	72 369 ℓ
Maximum capacity	84 056 ℓ

* Designed under licence to the General American Transportation Corporation.

WAGON DESCRIPTION

RAIL TANK CAR CLASS WJL

This vehicle is for the transportation of petroleum products from Kewdale to Country Depots.

The principal feature of construction is the use wherever possible, of aluminium alloy, resulting in a lighter vehicle giving more in payload.

Filling is achieved through pipes with apertures located on the top of the tank shell, whilst unloading is done via 100 mm outlet valves positioned at the bottom of the tank shell with piped connections to either side of the rail tank car.

GENERAL DATA

Owner	Shell Oil Company of Australia, Ltd.
Designer	Westrail *
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	March, 1973
Rail Gauge	1 435
Length over end sills	18 409
" over pulling faces of coupler	19 426
Bogie Centres	15 291
Maximum width	3 200
Maximum height (tare)	3 810
Capacity	91.85 m^3
Bogies	Wabcopac
Braking System	Air, Westinghouse ABSD
Handbrake	Ellcon, high powered
Coupler	F type 10A Contour Automatic
Weight - tare	20.3 t
- loaded (Gross)	95.25 t
Others - Load - Distillate (0.85 SG)	88 353 ℓ
- Motor spirit (0.93 SG)	80 752 ℓ
Maximum capacity	92 035 ℓ

* Designed under licence to the General American Transportation Corporation.

WAGON DESCRIPTION

RAIL TANK CAR CLASS WJK

This vehicle is for the transportation of petroleum products.

Having three separate compartments gives the rail tank car the flexibility of being suitable to carry a combination of products at any one time.

GENERAL DATA

Owner	Esso Oil Company of Australia, Ltd.
Designer	* Westrail
Manufacturer	Westrail Workshops, Midland, W.A.
Commissioned	November, 1970
Rail Gauge	1 435
Length over end sills	20 168
" over pulling faces of coupler	21 031
Bogie Centres	16 154
Maximum width	3 175
Maximum height (tare)	3 810
Capacity	98.88 m^3
Bogies	Wabcopac
Braking System	Air, Westinghouse ABSD
Handbrake	Miner D-3290-XL
Coupler	F type 10A Contour Automatic
Weight - Tare	23.88 t
" - Loaded (Gross)	95.26 t
Others - Load (0.85 SG)	83 304 ℓ
(0.76 SG)	89 627 ℓ
Maximum capacity	99 085 ℓ

* Designed under licence to the General American Transportation Corporation.

WAGON DESCRIPTION

RAIL TANK CAR CLASS JRB

This all aluminium rail tank car was designed for the transportation of petroleum products. It is a three compartment tank; each compartment being fitted with discharge valves and outlets thus enabling a combination of products to be transported at any one time.

Being of a monocoque design, this rail tank car is the first of its type to operate over this system.

GENERAL DATA

Owner	Mobil Oil Company of Australia
Designer	Tulloch Ltd., N.S.W.
Manufacture	Tulloch Ltd., N.S.W.
Commissioned	March, 1968
Rail Gauge	1 067
Length over end sills	15 900
" over pulling faces of coupler	16 738
Bogie Centres	12 547
Maximum width	2 514
Maximum height (Loaded)	3 708
Deck/Floor height (Loaded)	965
Bogies	10" x 5" journal roller bearings
Braking System	Vacuum (21 inch type F Cylinder)
Handbrake	Miner D-3290-XL
Coupler	Improved Yoke Drawgear
Height - Tare	15.08 t
Others - Maximum capacity (0.85 SG)	53 452 ℓ

WAGON DESCRIPTION

HOPPER WAGON CLASS XNG

This wagon has been designed for the conveyance of salt from the deposits at Lake Lefroy to Esperance on the south coast of Western Australia.

The use of all welded aluminium alloy construction techniques has helped to gain a high tare weight, pay load ratio.

The loading of the train is carried out as each wagon is spotted under the one hundred tonne capacity overhead bin, from which salt is discharged through three metre long pneumatically operated dump door. Each wagon is spotted twice under the dump door for a capacity fill, which loads 50 wagons per hour.

Unloading is carried out at a rate of 25 wagons per hour, by spotting each wagon over an under-track hopper, and releasing three manually operated levers.

GENERAL DATA

Owners	Norseman Gold Mines NL Lefroy Salt Pty. Ltd.
Designer	Commonwealth Engineering (Qld.)
Manufacturer	Commonwealth Engineering (Qld.)
Commissioned	November, 1969
Rail Gauge	1 067
Length over end sills	11 938
" over pulling faces of coupler	12 879
Bogie Centres	8 559
Maximum width	2 743
Maximum height (Loaded)	2 752
Capacity	38.65 m^3
Bogies	* Auscopac ride control
Braking System	Air, Westinghouse WF2
Hand Brake	Miner D-3290-XL
Coupler	Type E 10A Contour Automatic
Weight - Tare	13 t
" - Loaded (Gross)	60.9 t

* This wagon is suitable for conversion to Standard Gauge operation.

SECTION 17.

WAGON OUTLINES.

The opening remarks at Section 16 "Wagon Descriptions" apply equally to this section.

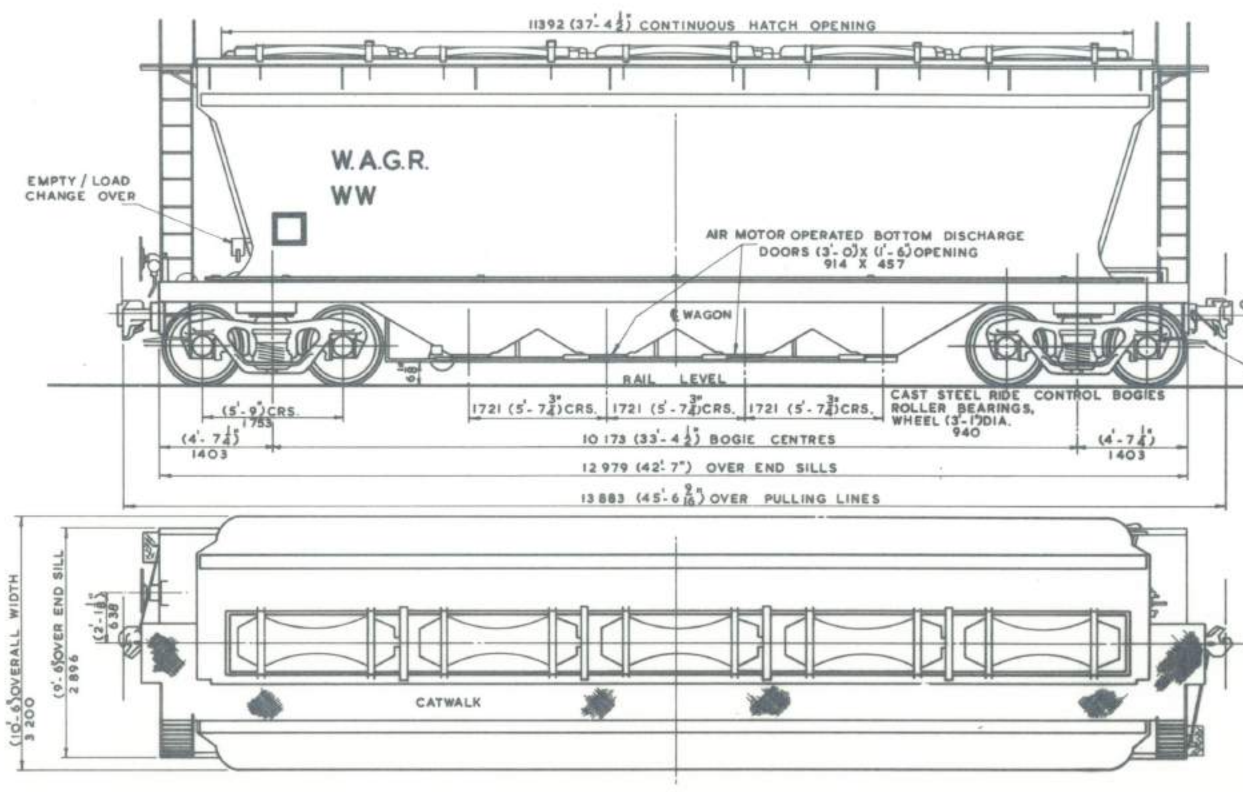
However, the sequence of Outlines has been re-arranged for easy reference to remarks in the body of this report.

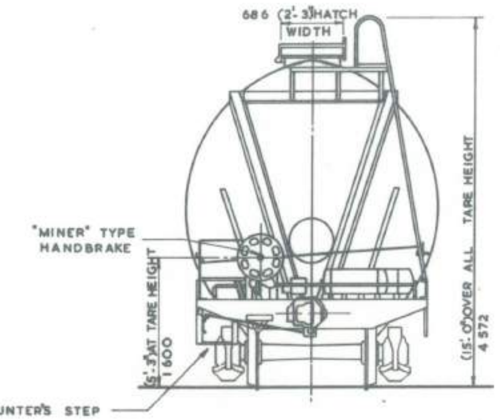
As previously indicated the Narrow Gauge "JTE" Rail Tank Wagon, the Standard Gauge "WW" Wheat Wagon and the Standard Gauge "WST" Rail Tank Wagon are all-steel vehicles included as datums for comparison purposes.

The Narrow Gauge "XB" was the original composite Bauxite Wagon and the remaining Outlines are of all-aluminium construction i.e. excluding proprietory lines.

Outlines have been listed, viz :-

W-O





BODY ARRG'T.	DRG. No. 51661
BOGIES 4'-8½" GAUGE	DRG. No. 50466 A AR 2D
JOURNAL SIZE	11" X 6" EQUIVALENT
WEIGHT ON RAIL	(93T - 15C - 0Q) 95 254 kg
TARE	(24T - 13C - 0Q) 25 045 kg
LOAD	(69T - 2C - 0Q) 70 209 kg
AIR BRAKE	WESTINGHOUSE (A.B.S.D)
BRAKE CYLINDER	U.C. 14" DIA. X 7" STROKE
BRAKE % AIR (EQUIVALENT CAST IRON)	TARE 67·53 % / LOAD 34·83 %
BRAKE % HAND (EQUIVALENT CAST IRON)	TARE 79·61 % / LOAD 20·93 %
EMPTY / LOAD BRAKE	YES
GRADE CONTROL	No.
VOLUMETRIC CAPACITY	3150 CUBIC FEET

NOTE: METRIC EQUIVALENTS SHOWN TO NEAREST MILLIMETRE AND KILOGRAM

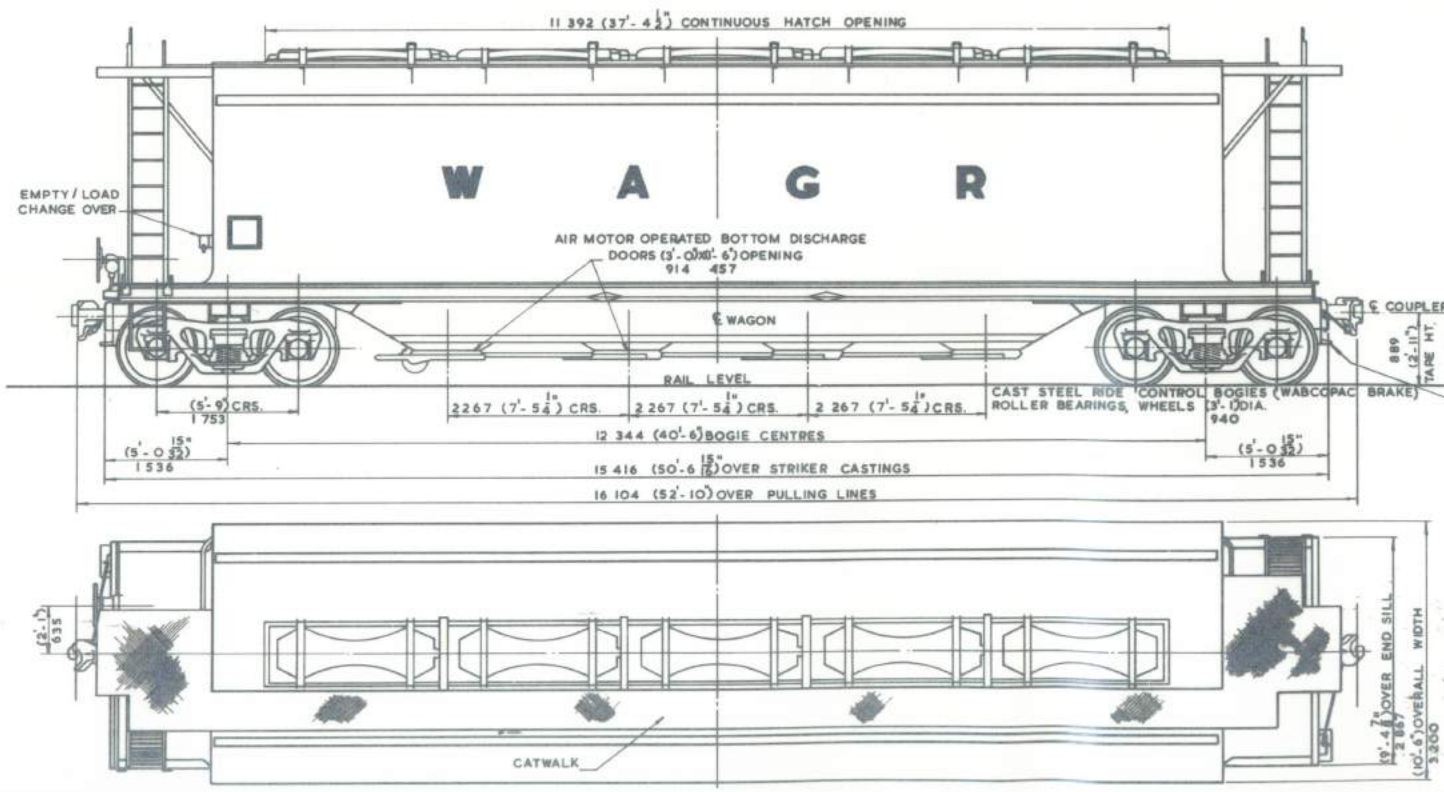
CHIEF MECHANICAL ENGINEER

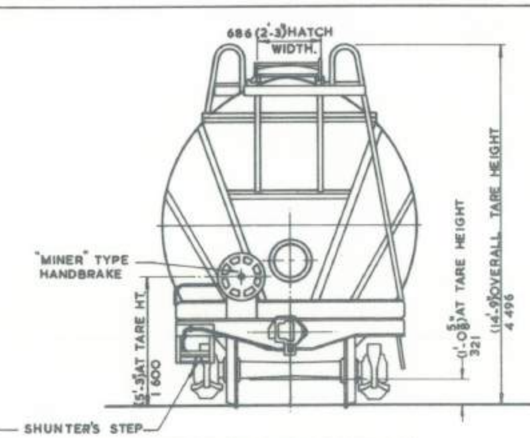
DIAG. No. 23/51300

W.A.G.R.	
CLASS	WW
WHEAT HOPPER WAGON	

DRN. E.M. 8-8-70
TCD. SW. 13.5.70
CKD. [illegible]
PDE. [illegible] 9-9-71

W-2





BODY ARRG'T.	DRG. No. 52235
BOGIES 4'-8½" GAUGE	DRG. No. 52490 A.AR. 2D
JOURNAL SIZE	11" X 6" EQUIVALENT
WEIGHT ON RAIL	(93T - 15C - 0Q) 95 254 kg
TARE	(19T - 2C - 1Q) 19 419 kg
LOAD	(74T - 12C - 3Q) 75 835 kg
AIR BRAKE	WESTINGHOUSE (WF2)
BRAKE CYLINDER	4 X 9" DIA. ON BOGIES
BRAKE % AIR (EQUIVALENT CAST IRON)	TARE 58·47 % / LOAD 29·82 %
BRAKE % HAND (EQUIVALENT CAST IRON)	TARE 43·15 % / LOAD 8·79 %
EMPTY LOAD BRAKE	YES
GRADE CONTROL	No
VOLUMETRIC CAPACITY	3 440 CUBIC FEET

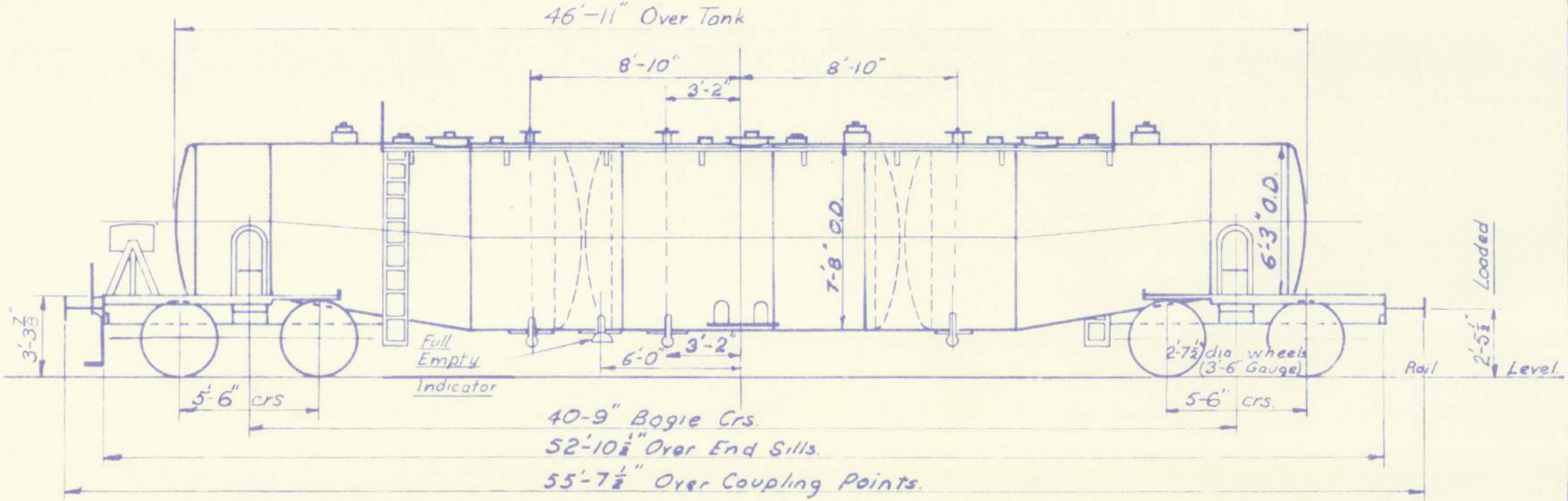
NOTE: METRIC EQUIVALENTS SHOWN TO NEAREST MILLIMETRE AND KILOGRAM.

CHIEF MECHANICAL ENGINEER

DIAG. No. 23A/51300

W.A.G.R.	
CLASS	WWA
WHEAT HOPPER WAGON	

DRN. E.M. 1-5-70
TCD. SW. 6.5.70
CKD. [illegible]
PDE. [illegible]



This Rail Tank Car has been designed for conversion to 4'-8$\frac{1}{2}$" Gauge.

Max specific gravity of product - 0·92.

2 End Compts - TOTAL CAP. 7,200 Galls For 3'-6" Gauge.
10,700 Galls For 4'-8$\frac{1}{2}$" Gauge.

W.A.G.R. OIL TANK CLASS. JTE

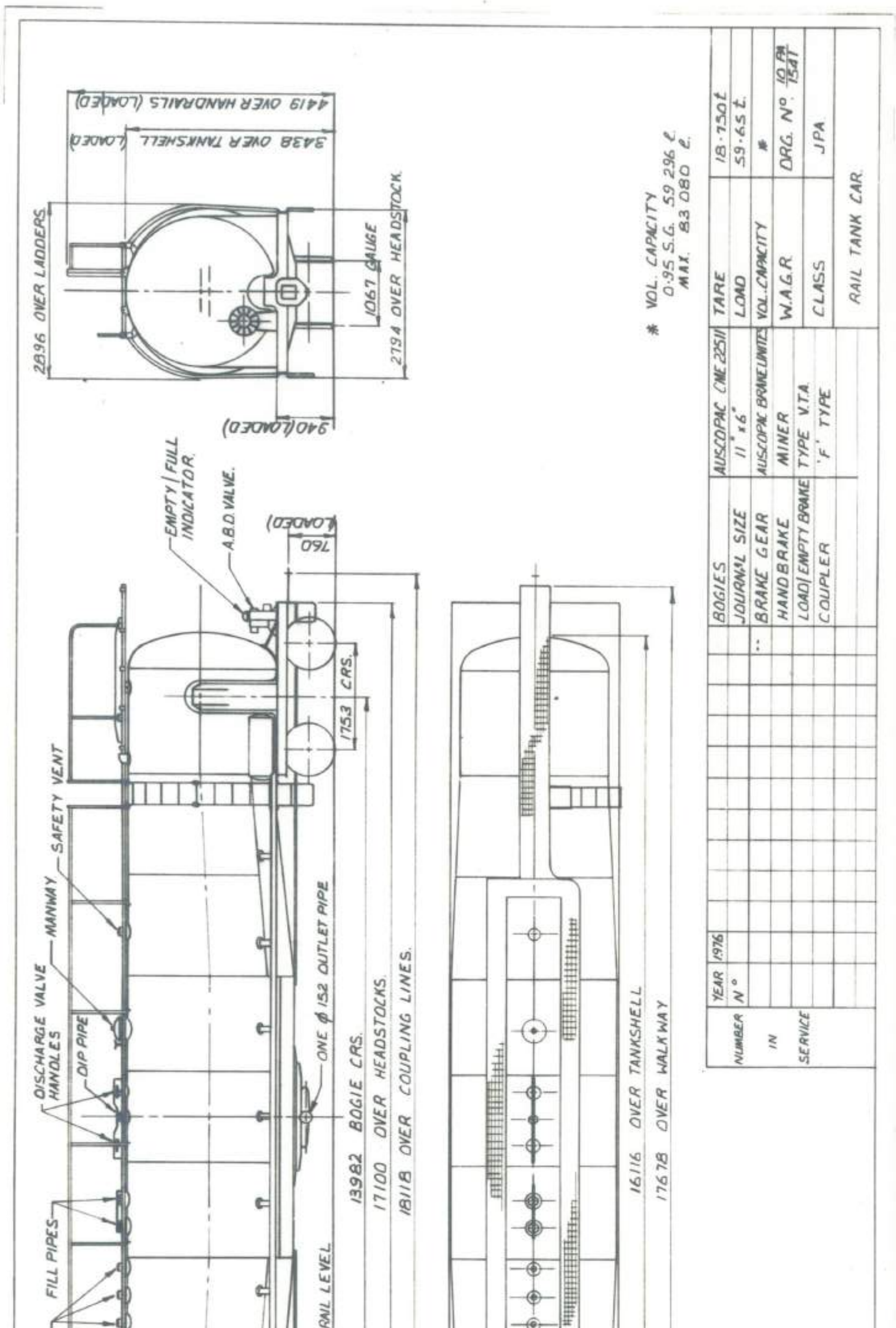
LOADING	TARE T-C-Q	LOAD T-C-Q	BRAKE
FUEL OIL PETROL & KERO	24-8-1	29-11-3	VAC & HAND

OWNER

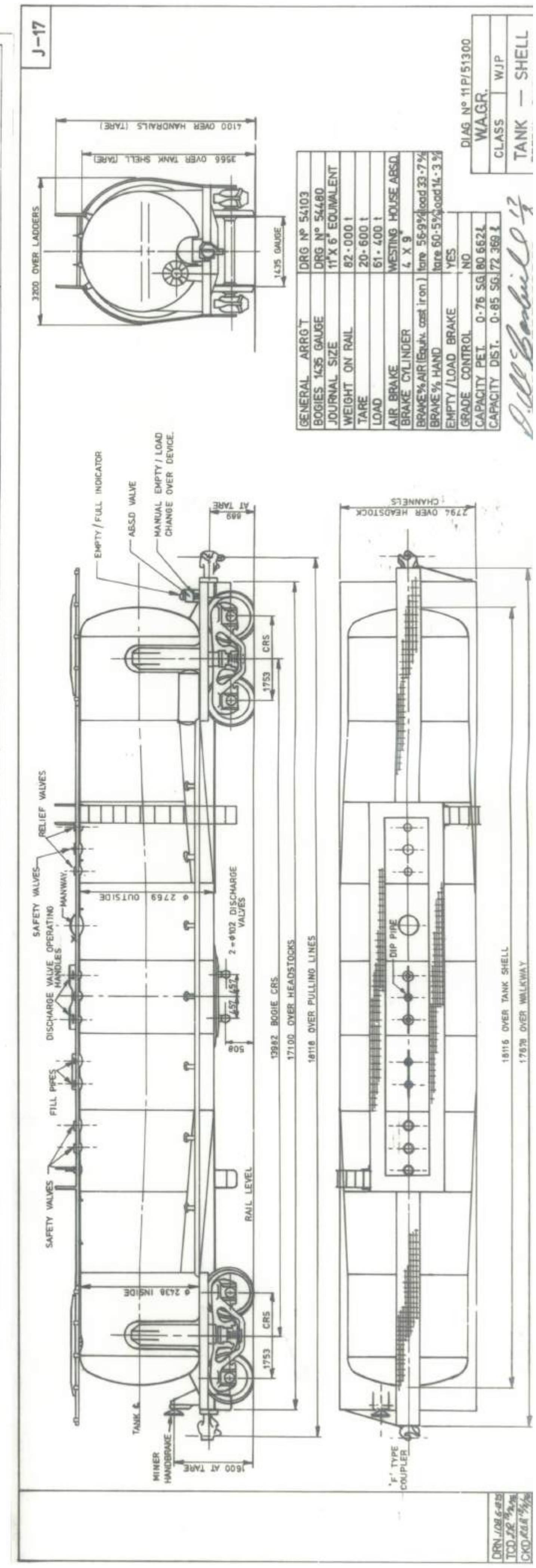
B.P. Ltd.

Number in Service	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Number		2	2	2	2	2	2	2	2	2	2	2		

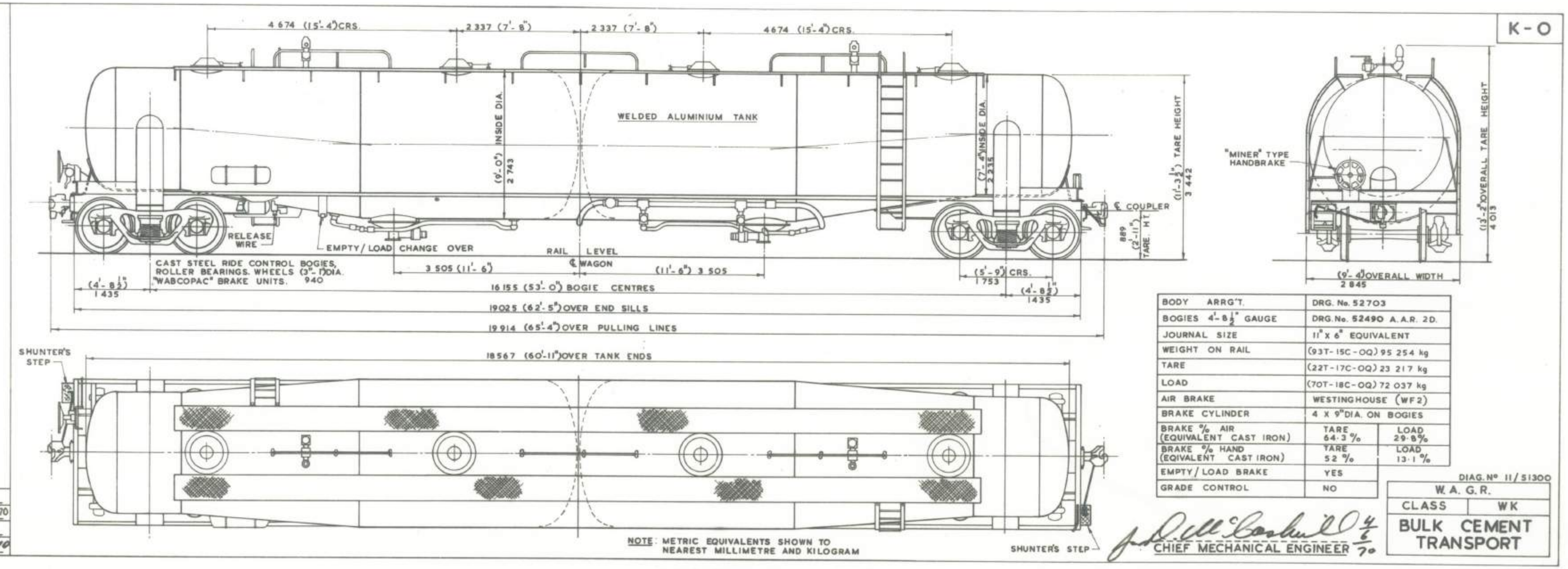
DRAWING N° 10 UE / 1541.



SAFETY VENT
FILL PIPES
DISCHARGE VALVE HANDLES
DIP PIPE
MANWAY
SAFETY VENT
EMPTY/FULL INDICATOR.
A.B.D. VALVE.
MINER HANDBRAKE.
1473 (LOADED)
1753 CRS.
ϕ 800 RAIL LEVEL
ONE ϕ 152 OUTLET PIPE
13982 BOGIE CRS.
17100 OVER HEADSTOCKS.
18118 OVER COUPLING LINES.
760 (LOADED)
16116 OVER TANKSHELL
17678 OVER WALKWAY
489
2896 OVER LADDERS
4419 OVER HANDRAILS (LOADED)
3438 OVER TANKSHELL (LOADED)
1067 GAUGE
2794 OVER HEADSTOCK
940 (LOADED)
* VOL. CAPACITY 0.95 S.G. 59 296 ℓ MAX. 83 080 ℓ.
NUMBER YEAR 1976
N°
IN SERVICE
BOGIES AUSCOPAC CME 2251 TARE 18·75 t
JOURNAL SIZE 11" x 6" LOAD 59·65 t.
BRAKE GEAR AUSCOPAC BRAKE UNITS VOL. CAPACITY *
HANDBRAKE MINER W.A.G.R. DRG. N° 10 PA 154 T
LOAD/EMPTY BRAKE TYPE V.T.A. CLASS JPA
COUPLER 'F' TYPE
RAIL TANK CAR.



J-17
SAFETY VALVES
FILL PIPES
DISCHARGE VALVE OPERATING HANDLES
SAFETY VALVES
MANWAY
RELIEF VALVES
EMPTY/FULL INDICATOR
ABSD VALVE
MANUAL EMPTY/LOAD CHANGE OVER DEVICE.
689 AT TARE
ϕ 2769 OUTSIDE
2-ϕ102 DISCHARGE VALVES
ϕ 2438 INSIDE
1753 CRS
RAIL LEVEL
13982 BOGIE CRS
17100 OVER HEADSTOCKS
18118 OVER PULLING LINES
1600 AT TARE
MINER HANDBRAKE
'F' TYPE COUPLER
TANK ℄
2794 OVER HEADSTOCK CHANNELS
DIP PIPE
16116 OVER TANK SHELL
17678 OVER WALKWAY
3200 OVER LADDERS
4100 OVER HANDRAILS (TARE)
3566 OVER TANK SHELL (TARE)
1435 GAUGE
GENERAL ARRGT DRG N° 54103
BOGIES 1435 GAUGE DRG N° 54480
JOURNAL SIZE 11" X 6" EQUIVALENT
WEIGHT ON RAIL 82·000 t
TARE 20·600 t
LOAD 61·400 t
AIR BRAKE WESTING HOUSE ABSD
BRAKE CYLINDER 4 X 9
BRAKE% AIR (Equiv. cast iron) tare 56·9% load 33·7%
BRAKE% HAND tare 60·5% load 14·3%
EMPTY/LOAD BRAKE YES
GRADE CONTROL NO
CAPACITY PET. 0·76 SG 80 662 ℓ
CAPACITY DIST. 0·85 SG 72 369 ℓ
DIAG N° 11P/51300
W.A.G.R.
CLASS WJP
TANK — SHELL



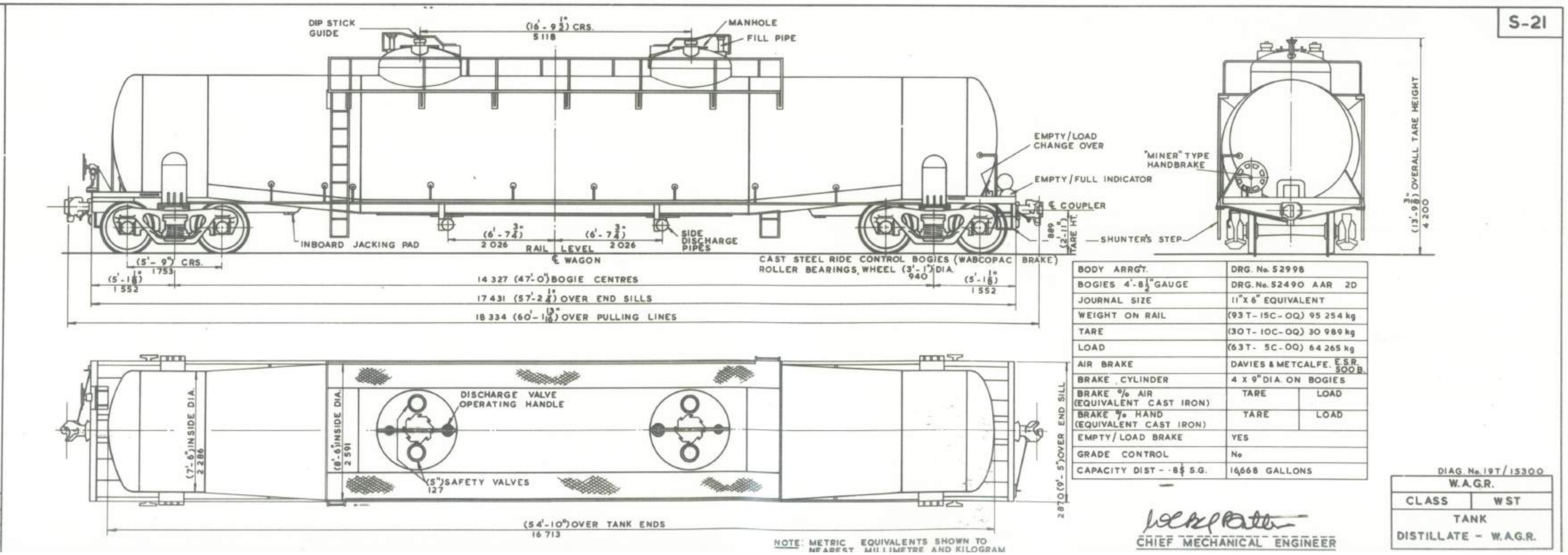
BODY ARRG'T.	DRG. No. 52703
BOGIES 4'-8½" GAUGE	DRG. No. 52490 A.A.R. 2D.
JOURNAL SIZE	11" x 6" EQUIVALENT
WEIGHT ON RAIL	(93T-15C-0Q) 95 254 kg
TARE	(22T-17C-0Q) 23 217 kg
LOAD	(70T-18C-0Q) 72 037 kg
AIR BRAKE	WESTINGHOUSE (WF2)
BRAKE CYLINDER	4 X 9" DIA. ON BOGIES
BRAKE % AIR (EQUIVALENT CAST IRON)	TARE 64·3 % / LOAD 29·8 %
BRAKE % HAND (EQUIVALENT CAST IRON)	TARE 52 % / LOAD 13·1 %
EMPTY/LOAD BRAKE	YES
GRADE CONTROL	NO

DIAG. Nº 11/51300

W. A. G. R.

CLASS	WK

BULK CEMENT TRANSPORT



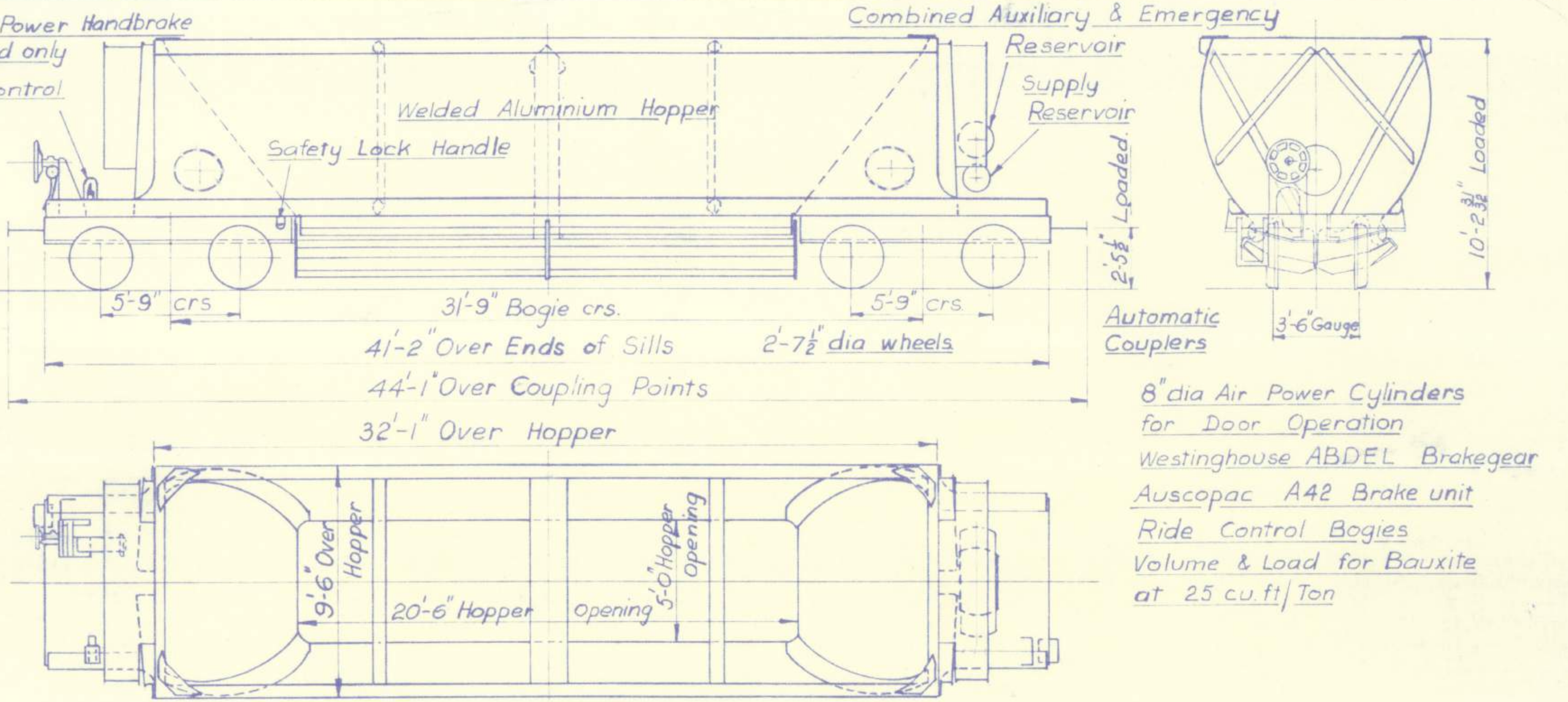
BODY ARRG'T.	DRG. No. 52998
BOGIES 4'-8½" GAUGE	DRG. No. 52490 AAR 2D
JOURNAL SIZE	11" x 6" EQUIVALENT
WEIGHT ON RAIL	(93T-15C-0Q) 95 254 kg
TARE	(30T-10C-0Q) 30 989 kg
LOAD	(63T-5C-0Q) 64 265 kg
AIR BRAKE	DAVIES & METCALFE E.S.R. 500 B.
BRAKE CYLINDER	4 X 9" DIA. ON BOGIES
BRAKE % AIR (EQUIVALENT CAST IRON)	TARE / LOAD
BRAKE % HAND (EQUIVALENT CAST IRON)	TARE / LOAD
EMPTY/LOAD BRAKE	YES
GRADE CONTROL	No
CAPACITY DIST - ·85 S.G.	16,668 GALLONS

DIAG. No. 19T/15300

W.A.G.R.

CLASS	WST

TANK DISTILLATE - W.A.G.R.

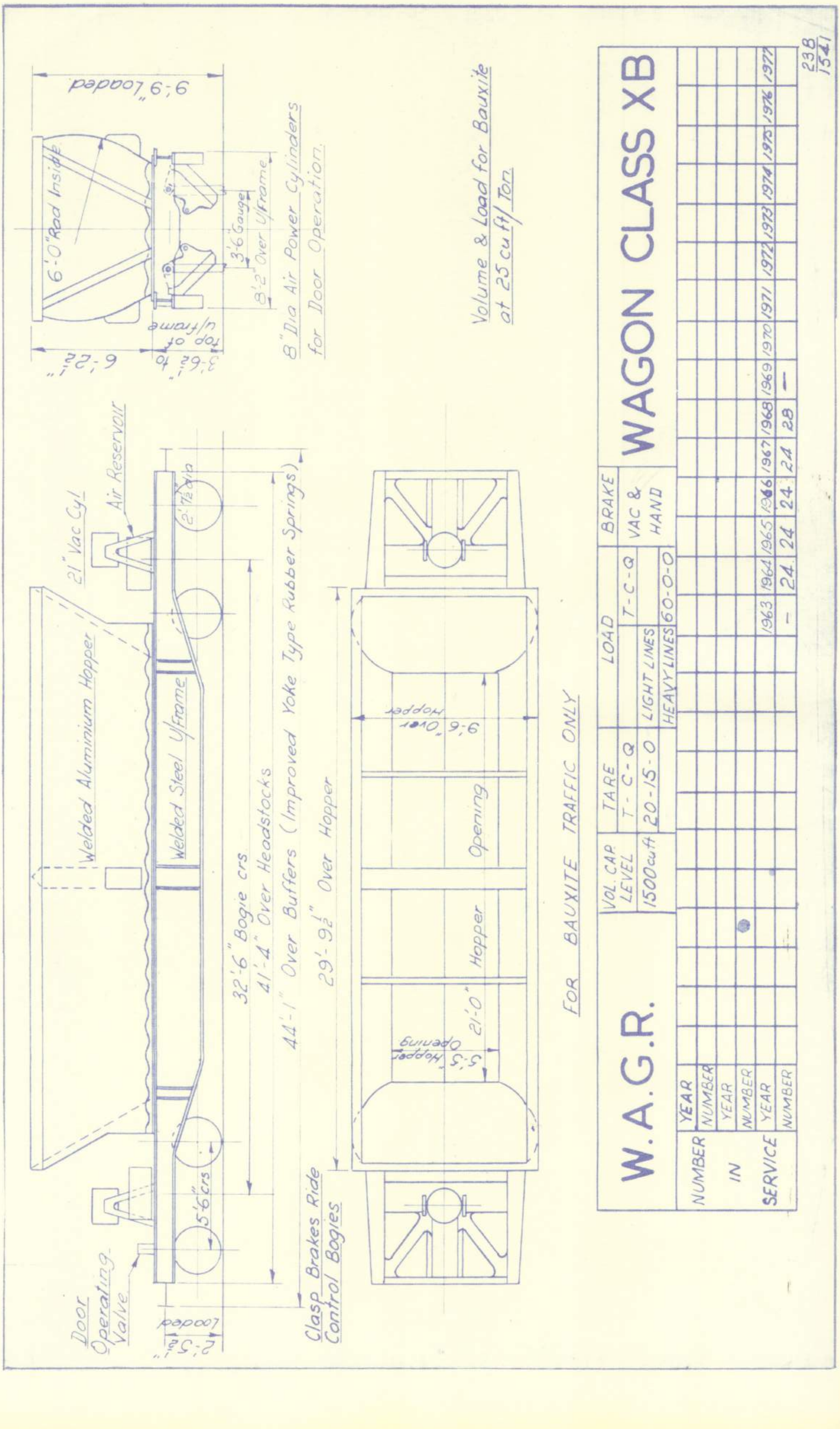


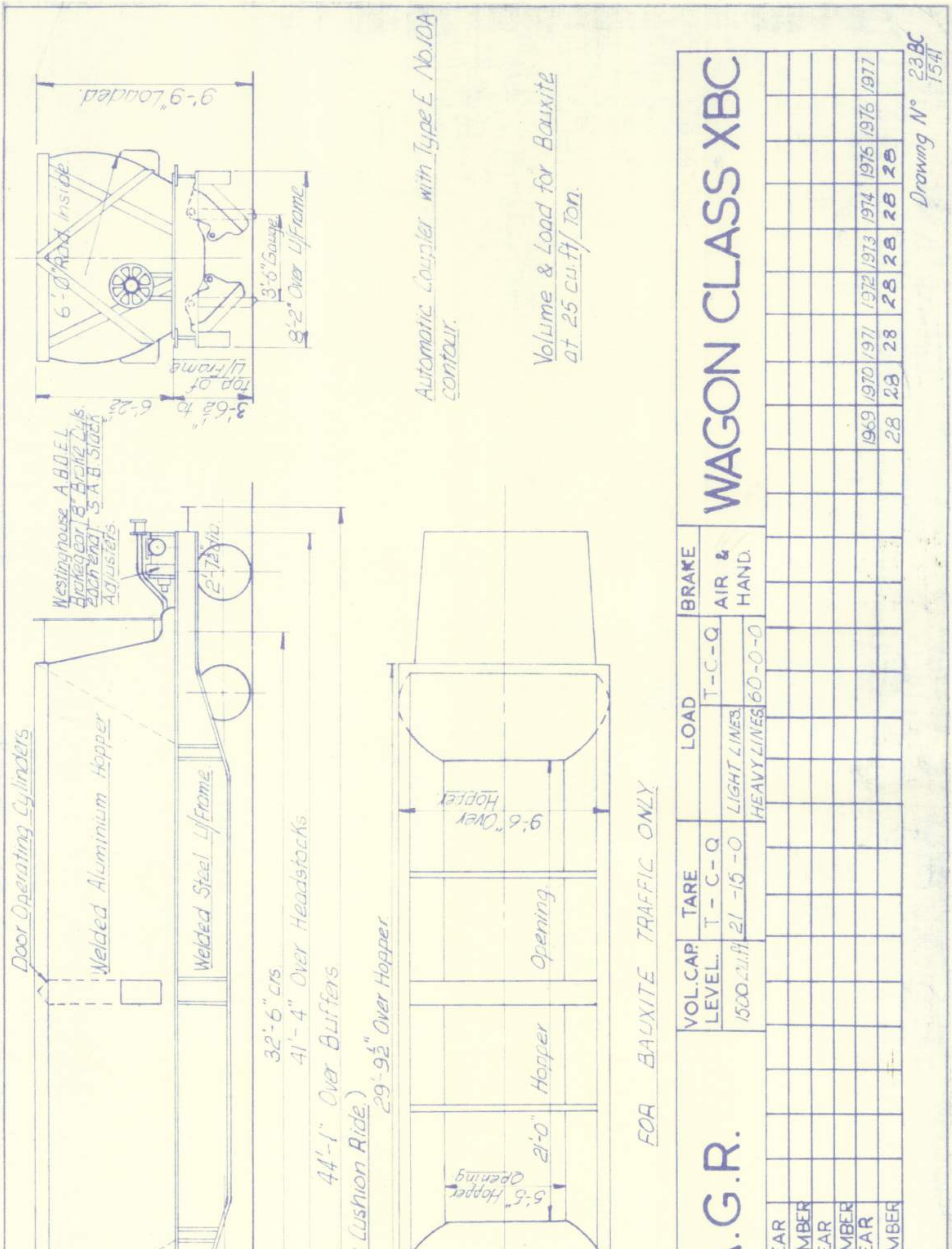
FOR BAUXITE TRAFFIC ONLY

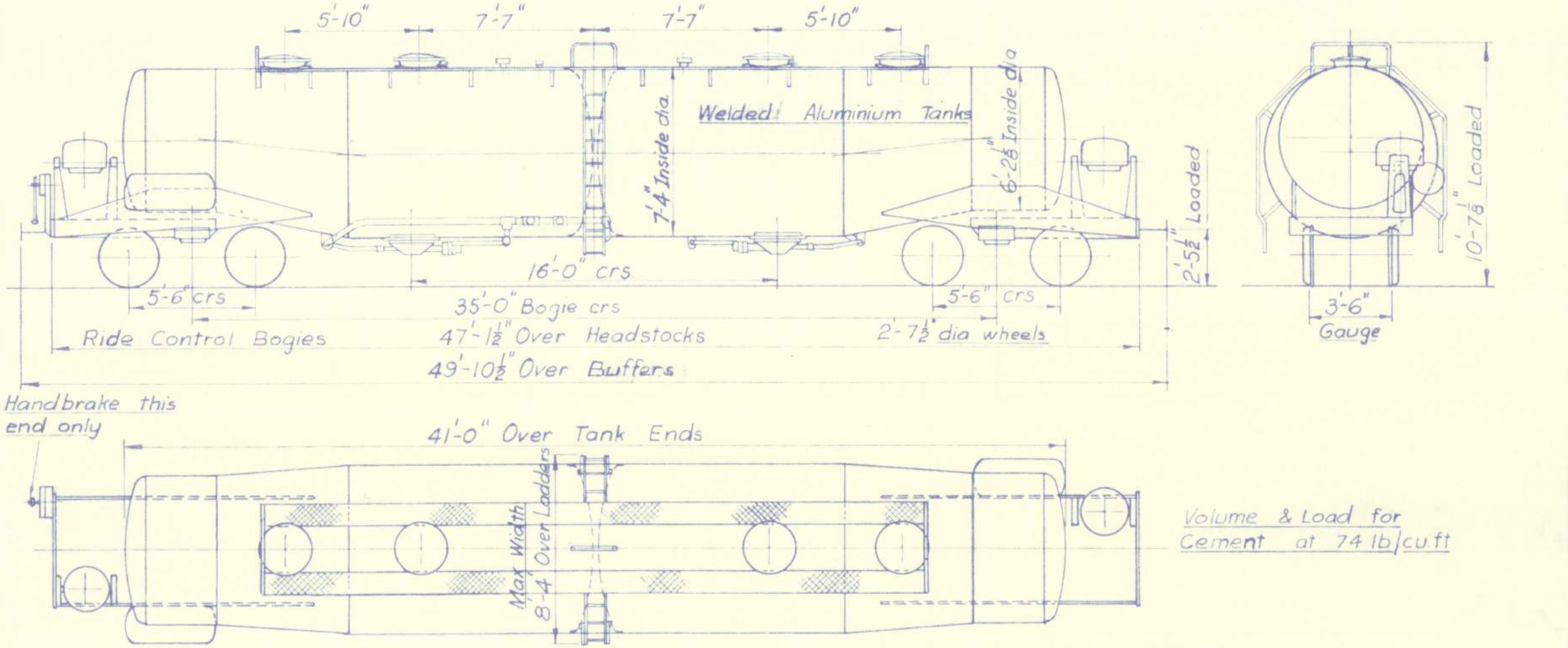
W.A.G.R.	VOL. CAP.	TARE	LOAD	BRAKE	WAGON CLASS XC
	1694 cu. ft	T-C-Q	T-C-Q	AIR &	
		17-2-0	62-18-0	HAND.	

NUMBER IN SERVICE												
YEAR	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
NUMBER	–	–	–	24	45	65	84	84	84	84		

23D
1541


W.A.G.R.
WAGON CLASS XB
VOL. CAP. LEVEL
1500 cu ft
TARE T-C-Q
20-15-0
LOAD T-C-Q
LIGHT LINES
HEAVY LINES 60-0-0
BRAKE
VAC & HAND
NUMBER IN SERVICE
YEAR
NUMBER
1963 1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977
– 24 24 24 24 28 —
238
1541
FOR BAUXITE TRAFFIC ONLY
Volume & Load for Bauxite at 25 cu ft/Ton.
8" Dia Air Power Cylinders for Door Operation.
6'-0" Rad Inside
9'-6" Loaded
6'-2¼"
3'-6¼" to top of u/frame
3'-6" Gauge
8'-2" Over U/frame
21" Vac Cyl
Air Reservoir
Welded Aluminium Hopper
Welded Steel U/Frame
2'-7½" dia
32'-6" Bogie crs
41'-4" Over Headstocks
44'-1" Over Buffers (Improved Yoke Type Rubber Springs)
29'-9½" Over Hopper
5'-6" crs
Door Operating Valve
2'-5¾" Loaded
Clasp Brakes Ride Control Bogies
9'-6" Over Hopper
Hopper Opening
21'-0"
5'-5" Hopper Opening


Door Operating Controls.
Door Operating Cylinders
Welded Aluminium Hopper
Welded Steel U/Frame
Westinghouse ABDEL Brakegear 18" Brake Cyls. Each end 3 A.B. Slack Adjusters.
2'-7½" dia.
5'-6" crs
2'-5½" Loaded
32'-6" crs
41'-4" Over Headstocks
44'-1" Over Buffers
Modified Bogies (Buckeye Cushion Ride.)
11"x6" Journals.
29'-9½" Over Hopper
9'-9" Loaded
6'-0" Rad. Inside
6'-2½"
3'-6½" to top of U/Frame
3'-6" Gauge
8'-2" Over U/Frame
Automatic Coupler with Type E No.10A contour.
Volume & Load for Bauxite at 25 cu.ft/Ton.
9'-6" Over Hopper
Hopper Opening
21'-0"
5'-5" Hopper Opening
FOR BAUXITE TRAFFIC ONLY
W.A.G.R.
WAGON CLASS XBC
VOL.CAP. LEVEL. 1500 cu.ft
TARE T-C-Q 21-15-0
LOAD T-C-Q LIGHT LINES HEAVY LINES 60-0-0
BRAKE AIR & HAND.
NUMBER IN SERVICE
YEAR NUMBER YEAR NUMBER YEAR NUMBER
1969 1970 1971 1972 1973 1974 1975 1976 1977
28 28 28 28 28 28 28
Drawing No 23BC/1541

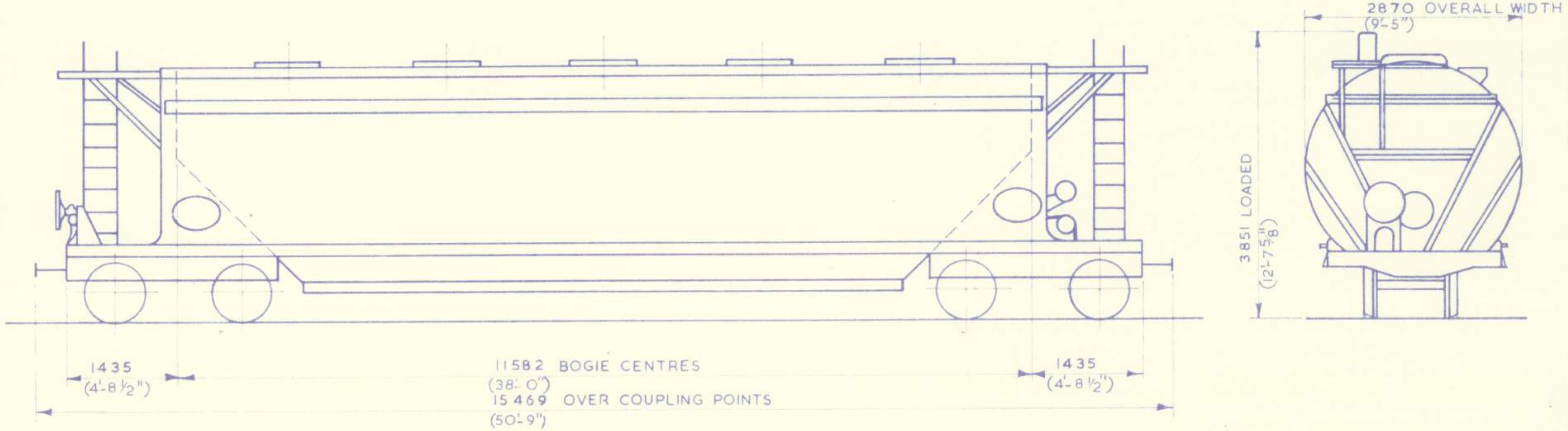


CEMENT TANKER

W.A.G.R	VOL. CAP. of cement	TARE T-C-O	LOAD T-C-O	BRAKE	WAGON CLASS XR
	1354 cuft.	14-19-0	45-1-0	Vacuum & Hand.	

NUMBER IN SERVICE												
YEAR	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
NUMBER	—	-	-	1	1	2	2	2	2	2		

23E
1541

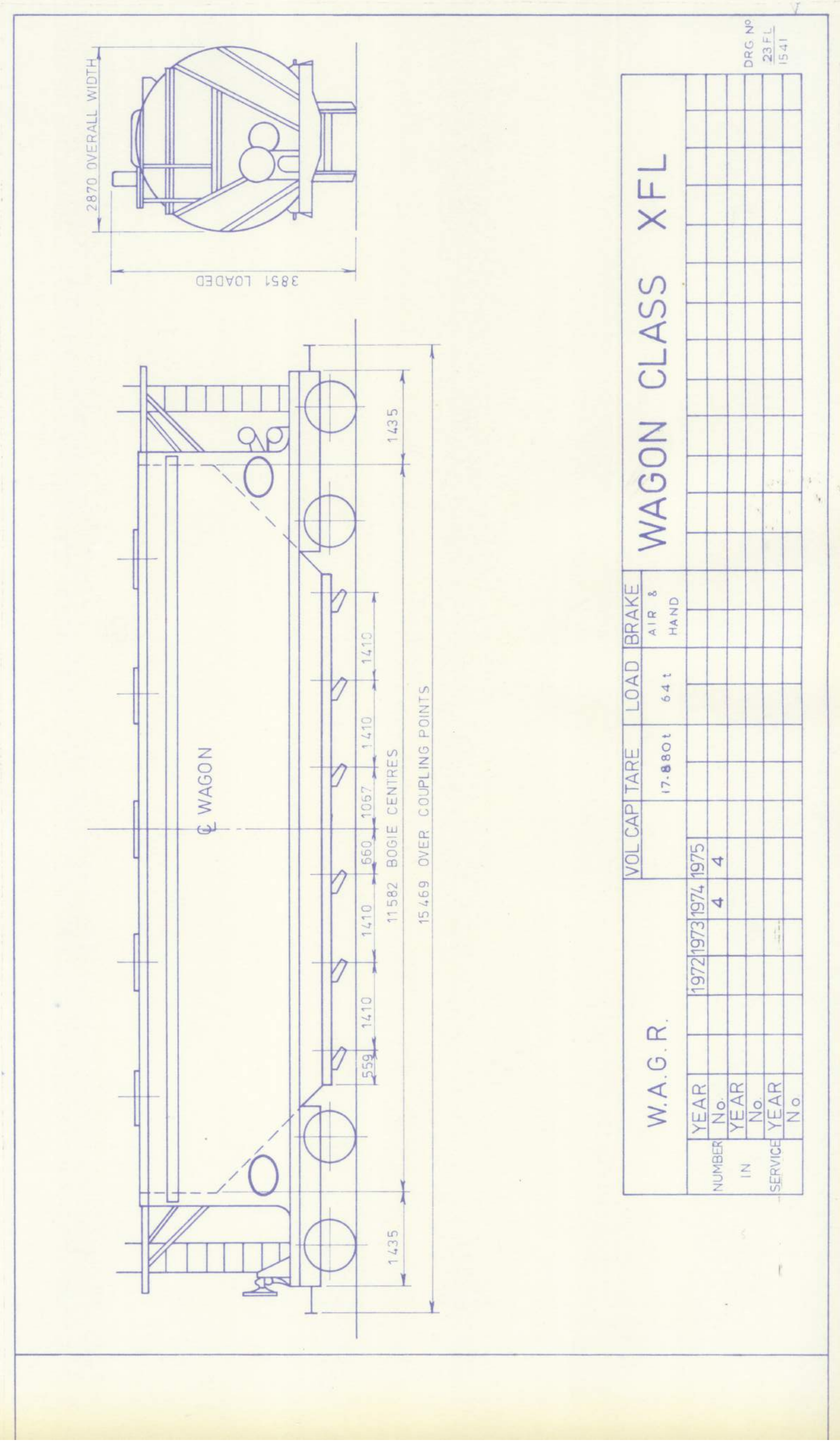


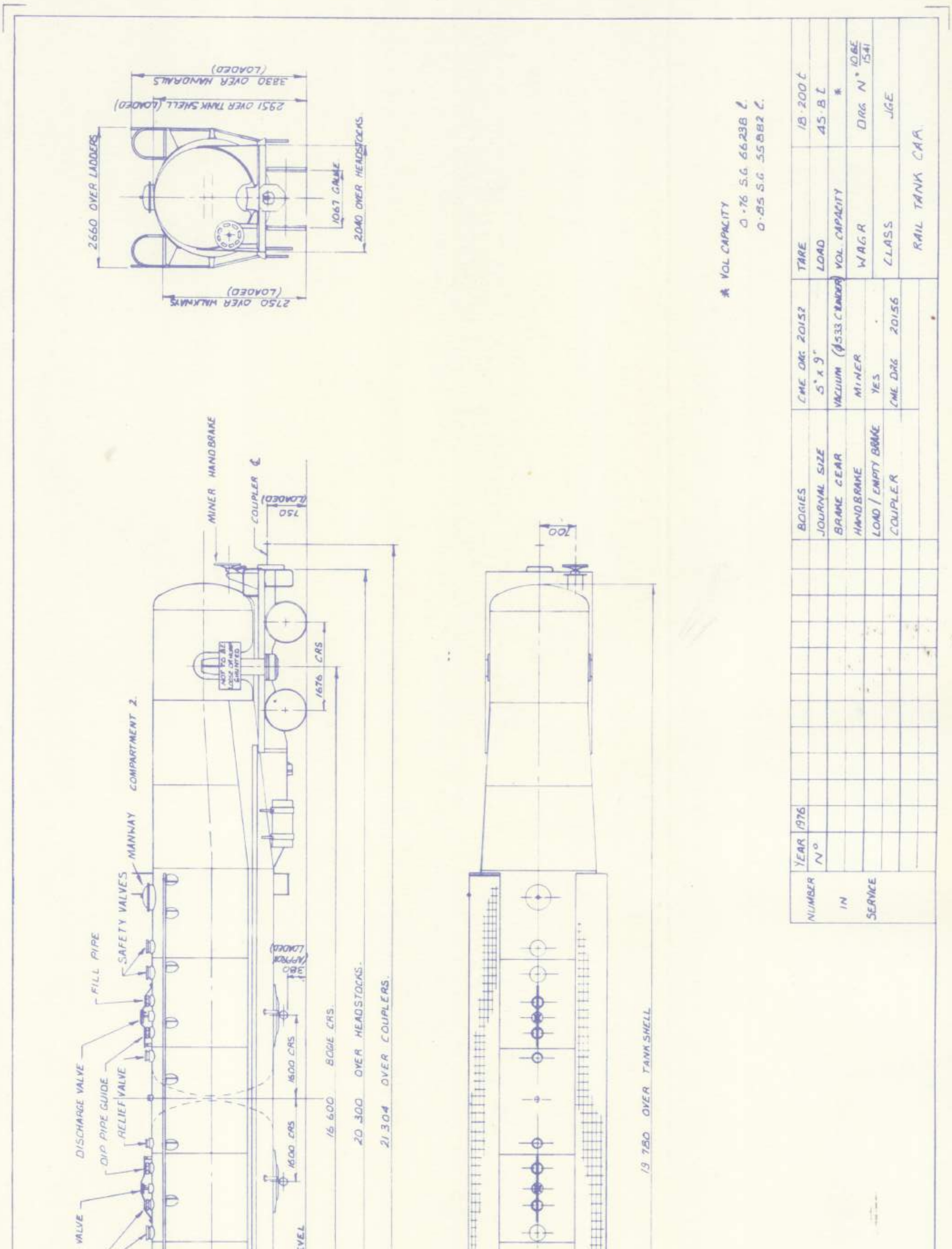
NOTE
METRIC EQUIVALENTS SHOWN
TO NEAREST MILLIMETRE
AND TONNES.

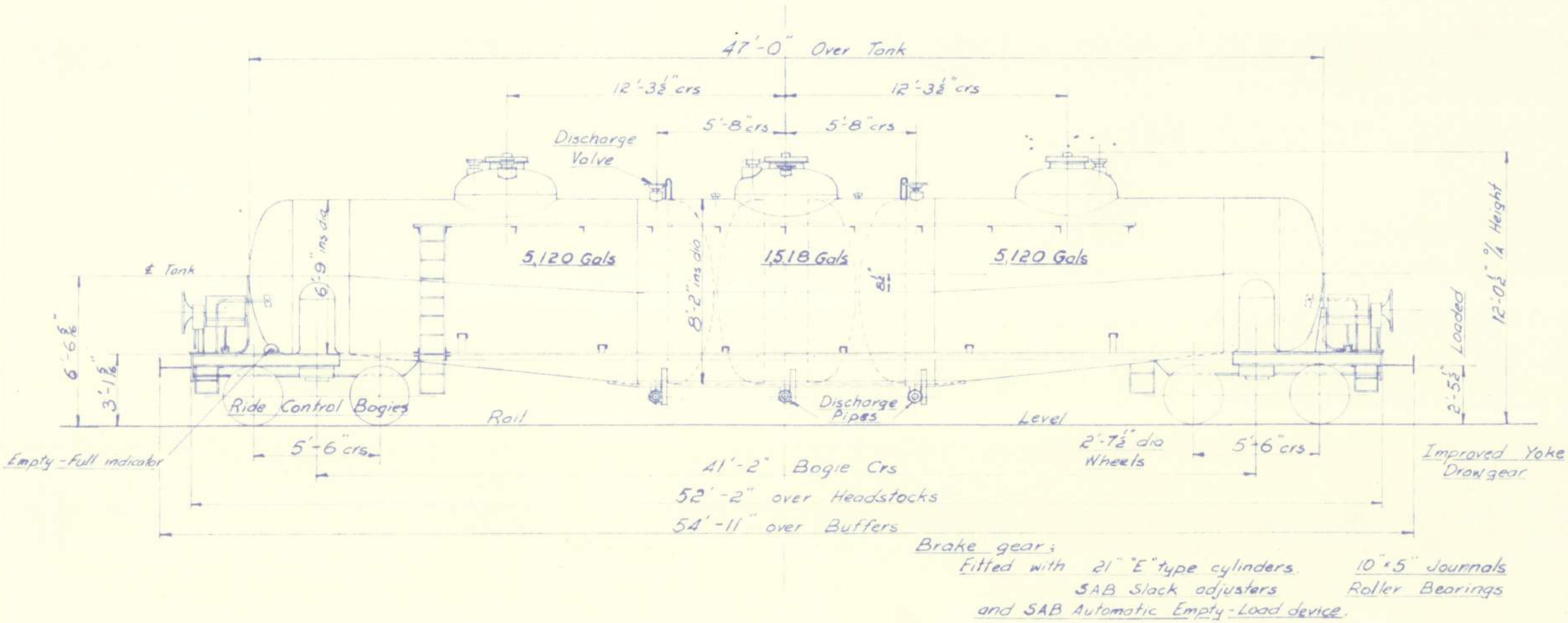
W.A.G.R.	VOL.CAP.	TARE	LOAD	BRAKE	WAGON CLASS XF.
	69.4 m^3 (2450 ft^3)	18.2 t (18.0.0)	62.9 t (62.0.0)	AIR & HAND	

NUMBER	YEAR	1970	1971	1972	1973	1974	1975																	
	No.		—	14	27	31	31																	
IN	YEAR.																							
	No																							
SERVICE	YEAR																							
	No.																							

DRG. No. 23 F / 1541


2870 OVERALL WIDTH
3851 LOADED
℄ WAGON
1435
1410
1410
1067
660
1410
1410
559
1435
11582 BOGIE CENTRES
15469 OVER COUPLING POINTS
W.A.G.R.
WAGON CLASS XFL
VOL CAP
TARE
17.880t
LOAD
64t
BRAKE
AIR & HAND
NUMBER IN SERVICE
YEAR
No.
1972
1973
1974
4
1975
4
DRG Nº 23FL 1541


2660 OVER LADDERS
1067 GAUGE
2040 OVER HEADSTOCKS
2750 OVER WALKWAYS (LOADED)
2951 OVER TANK SHELL (LOADED)
3830 OVER HANDRAILS (LOADED)
COMPARTMENT 1
COMPARTMENT 2
MANWAY
FILL PIPE
SAFETY VALVES
DISCHARGE VALVE
DIP PIPE GUIDE
RELIEF VALVE
MINER HANDBRAKE
COUPLER ℄
TANK ℄
EMPTY/FULL INDICATOR
NOT TO BE LOOSE SHUNTED
1525 (LOADED)
750 (LOADED)
380 (APPROX) (LOADED)
1676 CRS
1600 CRS
Ø 800
RAIL LEVEL
16 600 BOGIE CRS.
20 300 OVER HEADSTOCKS.
21 304 OVER COUPLERS.
19 780 OVER TANK SHELL
700
* VOL CAPACITY
0·76 S.G. 66238 ℓ
0·85 S.G. 55882 ℓ
NUMBER IN SERVICE
YEAR 1976
N°
BOGIES — CME DRG 20152
JOURNAL SIZE — 5" x 9"
BRAKE GEAR — VACUUM (Ø533 CYLINDER)
HANDBRAKE — MINER
LOAD / EMPTY BRAKE — YES
COUPLER — CME DRG 20156
TARE — 18·200 t
LOAD — 45·8 t
VOL CAPACITY — *
WAGR — DRG N° 10BE/1541
CLASS — JGE
RAIL TANK CAR



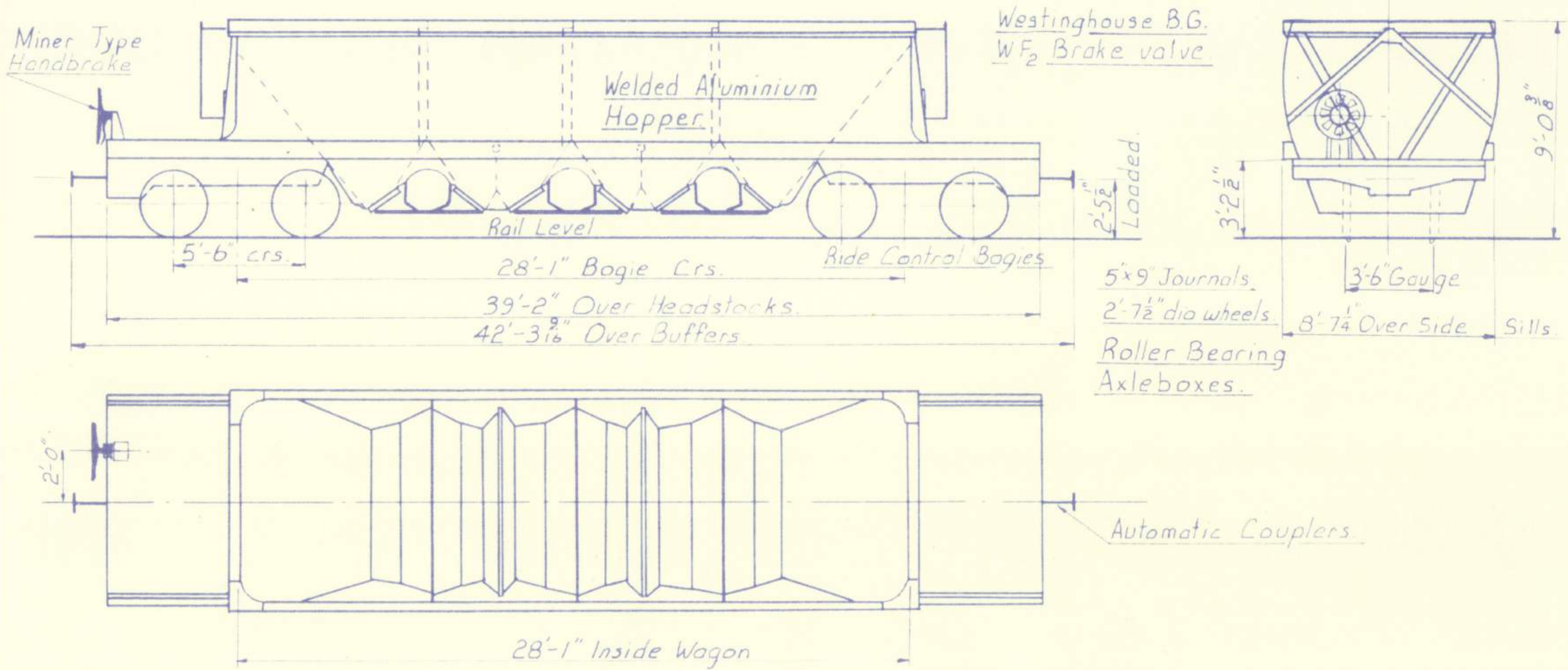
Fully welded aluminium tanker LOADED CAPACITY = 11,758 Gals MOBIL OIL C^OY

W. A. G. R. OIL TANK. CLASS. JRB

LADING	TARE T-C-Q	LOAD T-C-Q	BRAKE
FUEL OIL	14-17-3	—	VACUUM & HAND
PETROL & KERO	14-17-3	—	

Number in Service										
	Year	1967	1968	1969	1970	1971	1972	1973	1974	1975
	Number	—	1	1	1	1	3	3	3	3
	Year									
	Number									
	Year									
	Number									

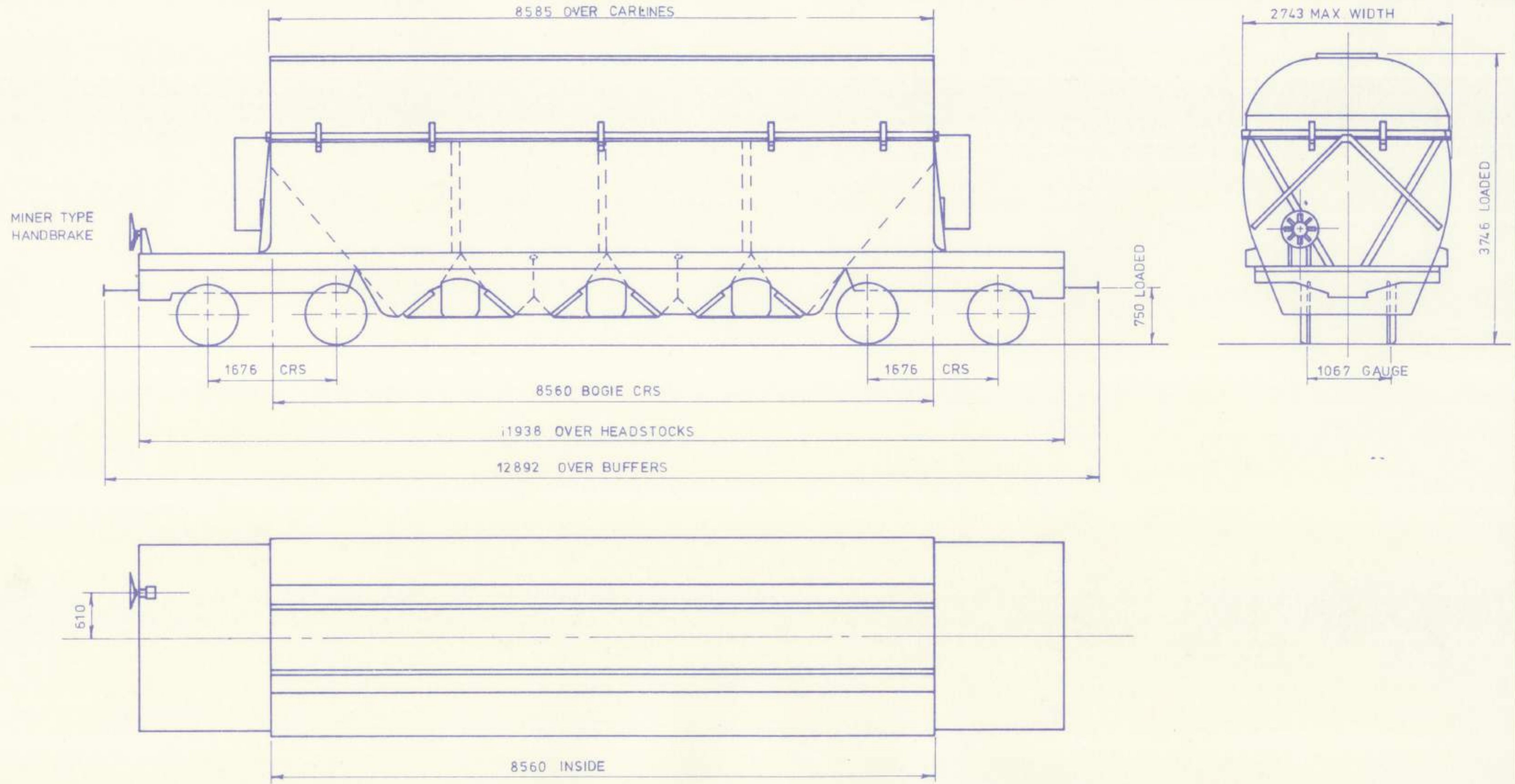
DRAWING N° 10SB/1541



W.A.G.R.	TARE	LOAD	BRAKE	VOL CAP	WAGON CLASS XNG
	T-C-Q	T-C-Q	HAND &	CU.FT.	
	12-16-0	47-4-0	AIR.	1,365	

NUMBER IN SERVICE						
YEAR	1970	1971	1972	1973	1974	1975
NUMBER	25	25	40	40	40	—

DRAWING NO 23 NG / 1541

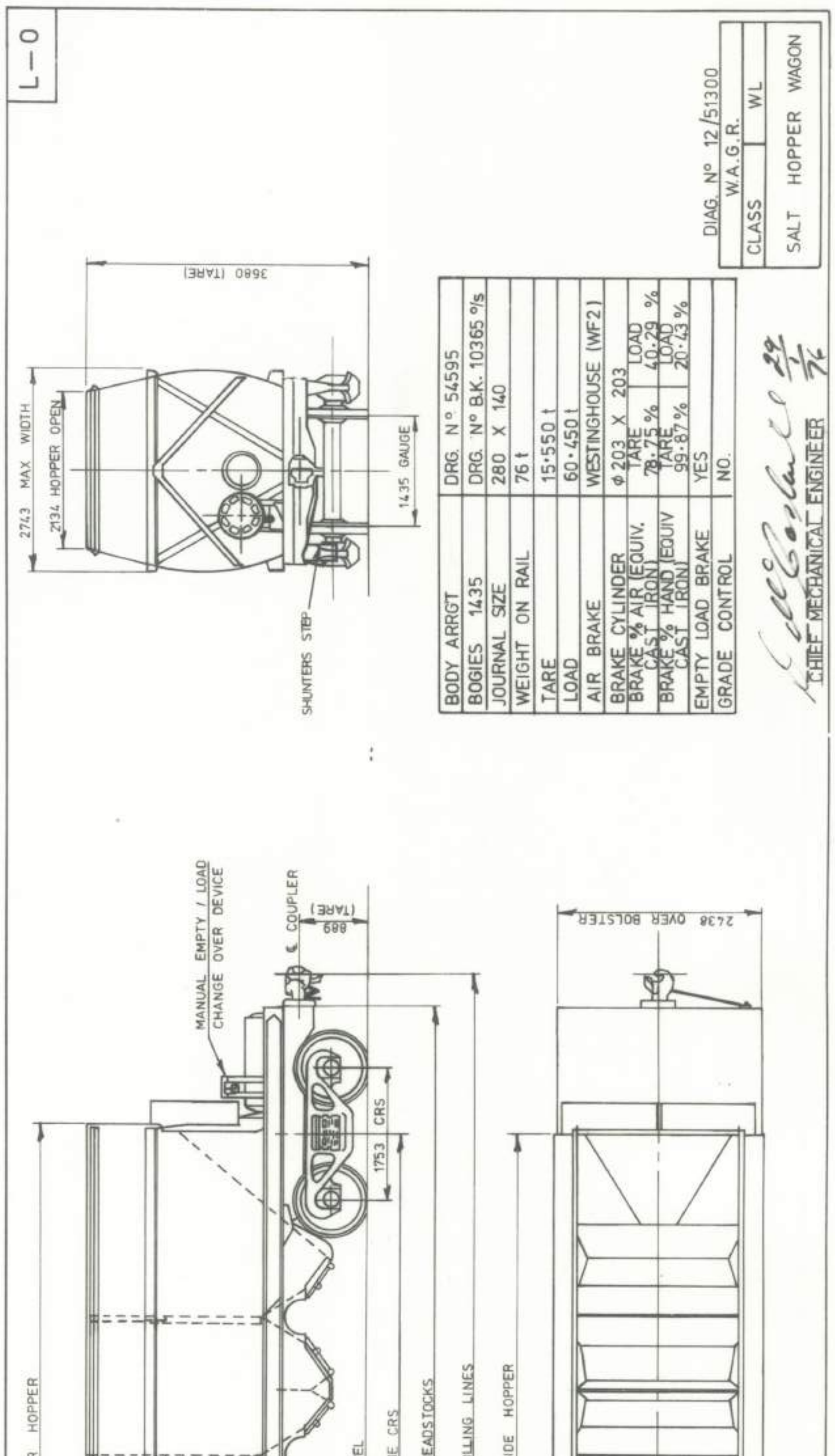


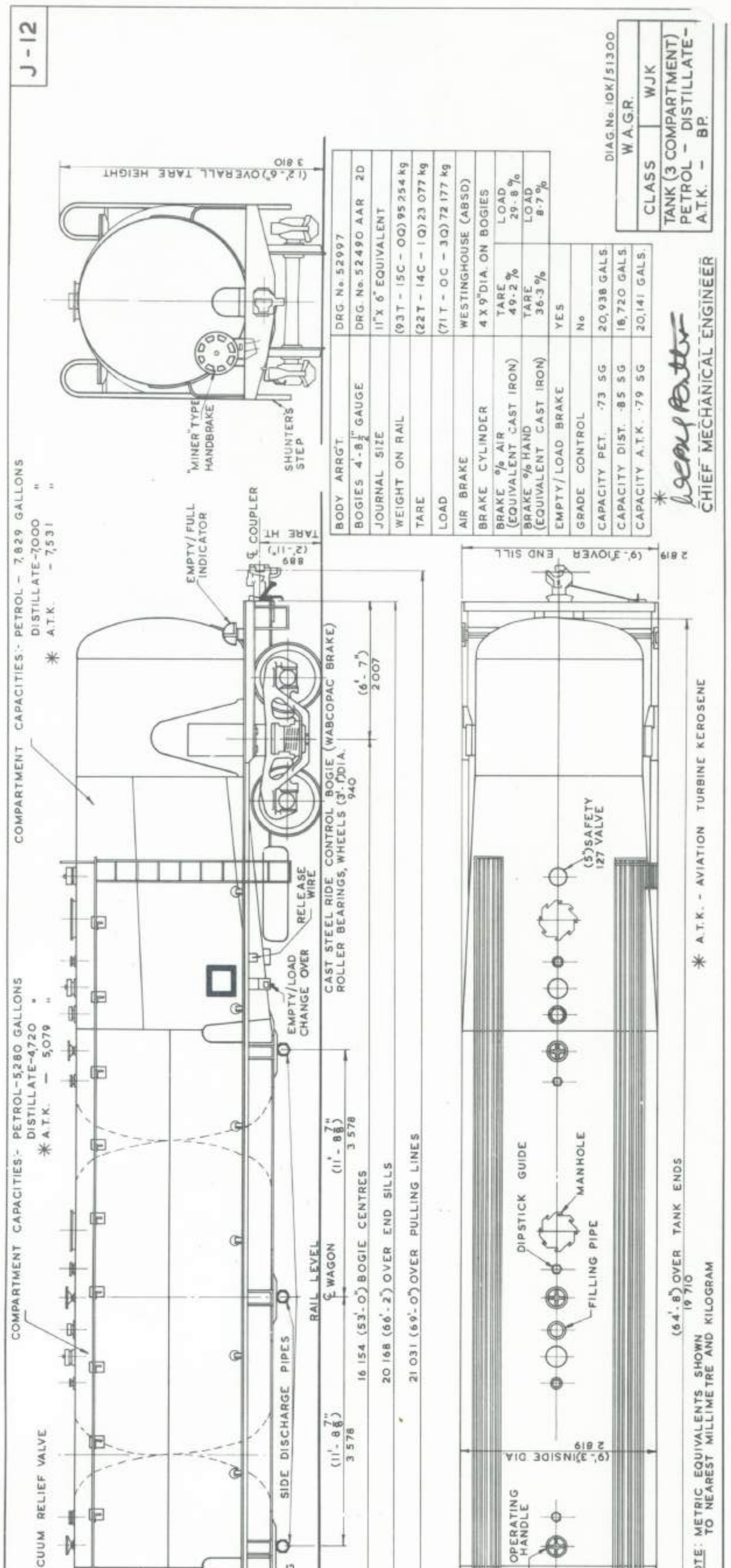
✱ THROUGH PIPE FOR OPERATION IN VACUUM BRAKE TRAINS

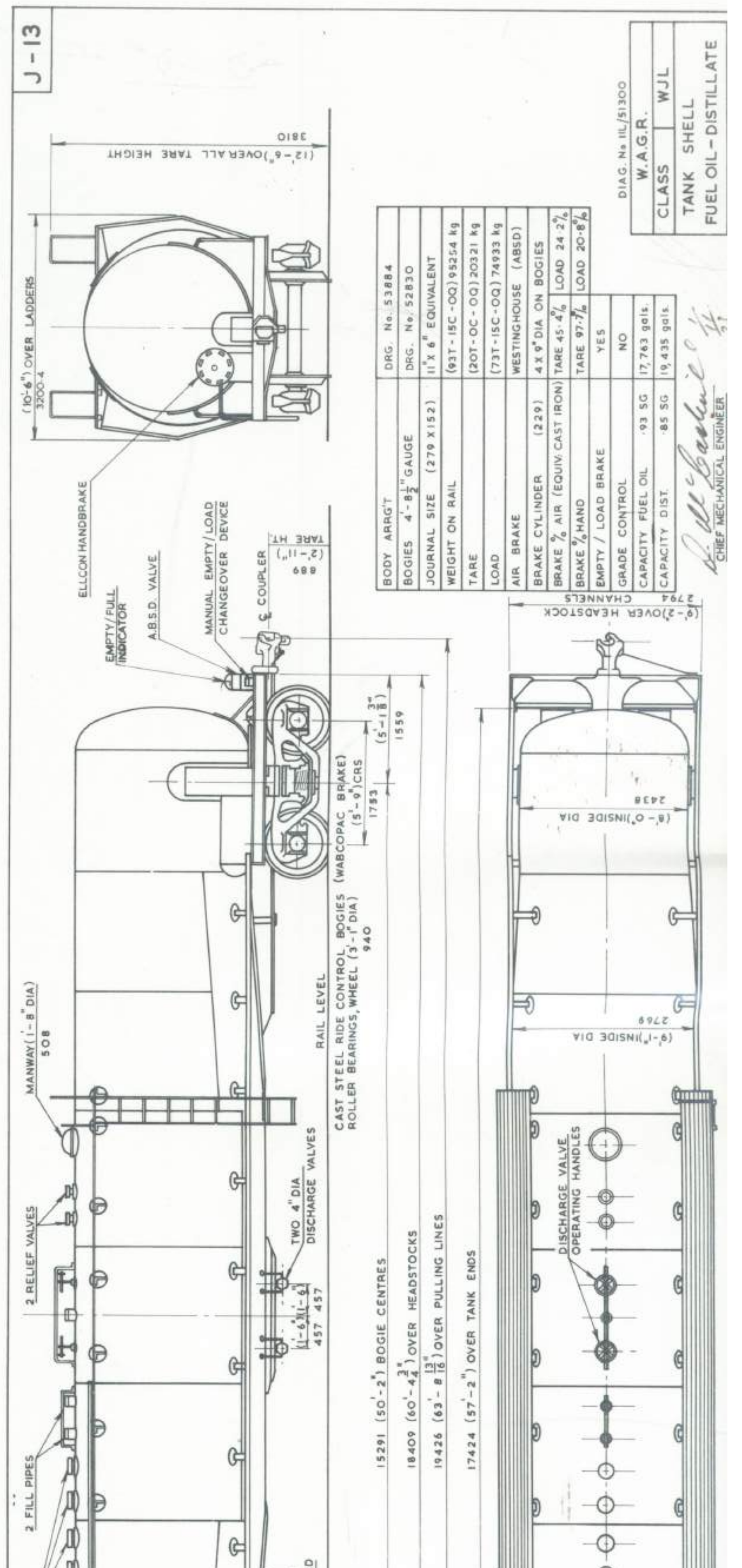
NUMBER IN SERVICE	YEAR	1974	1975	1976	1977	1978	1979	1980				
	N°	18										

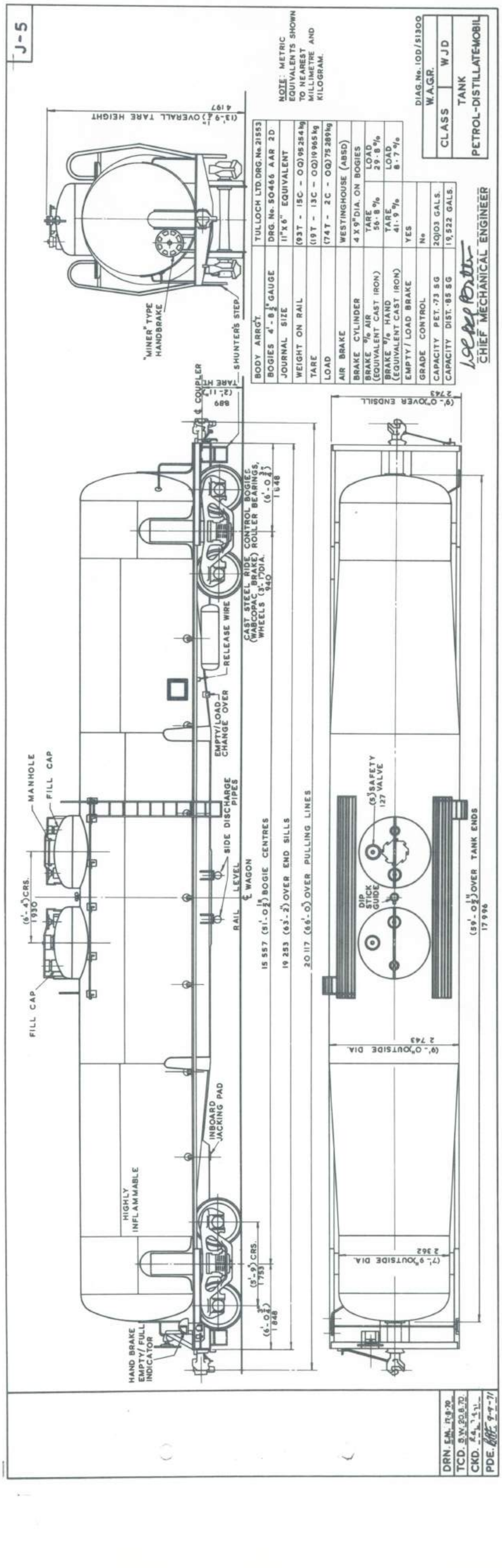
BOGIE	C.M.E. N° 23192
JOURNAL SIZE	5" X 9"
BRAKE GEAR	W/HOUSE WF 2 ✱
HAND BRAKE	MINER
LOAD/EMPTY BRAKE	MANUAL
COUPLER	'E' TYPE
CONVERTED FROM XNG.	

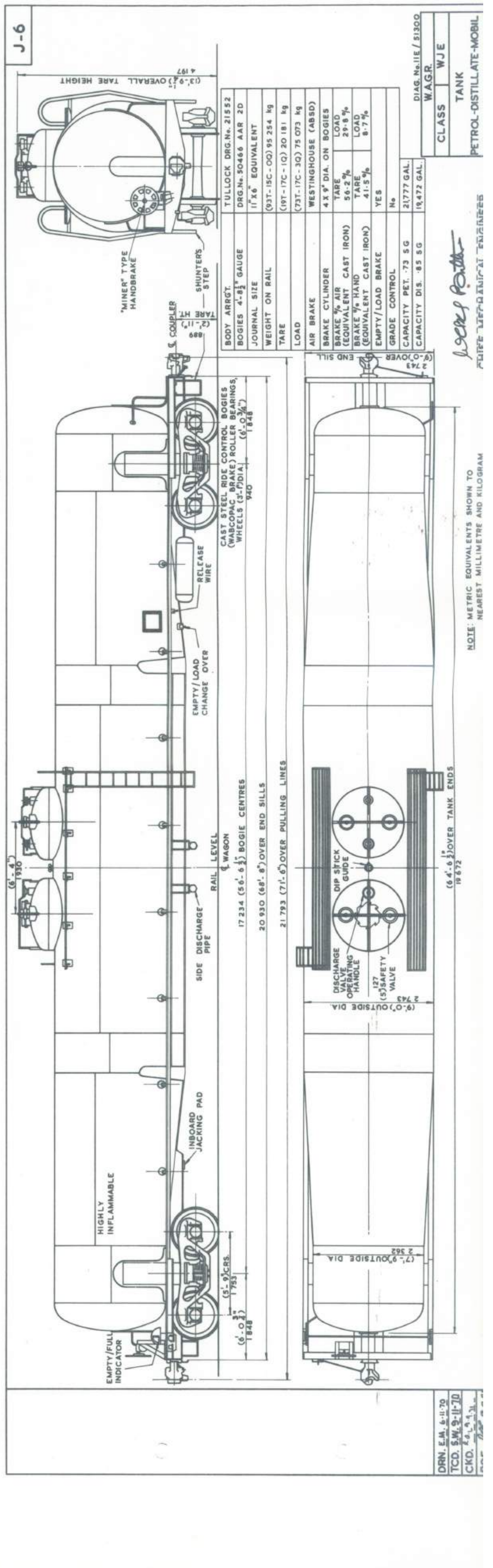
TARE	13 – 769 t
LOAD	50 t
VOL. CAPACITY	
W.A.G.R.	DRG.N°
CLASS	X N
COAL HOPPER	

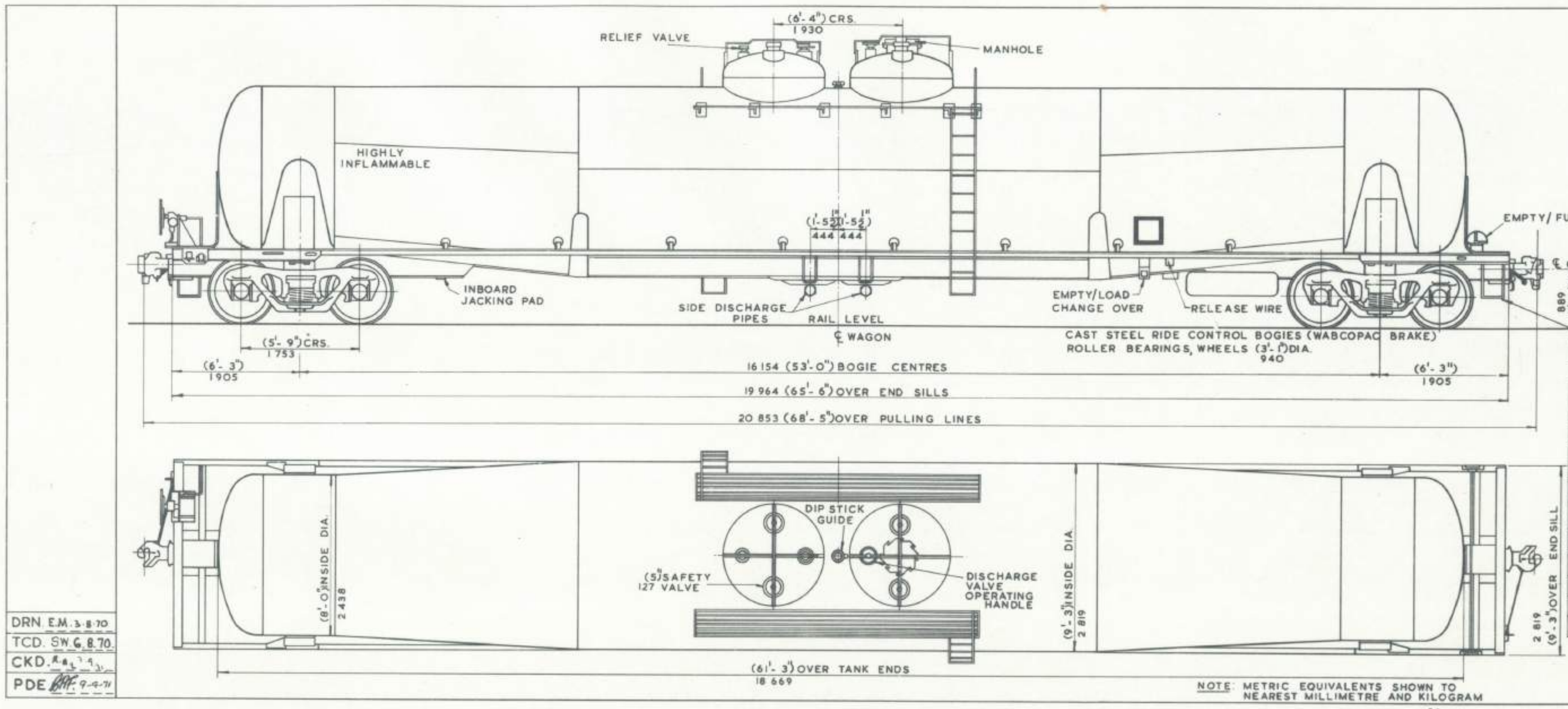

L—0
8814 OVER HOPPER
MINER HANDBRAKE
MANUAL EMPTY / LOAD CHANGE OVER DEVICE
℄ COUPLER
1589
889 (TARE)
RAIL LEVEL
1753 CRS
1753 CRS
8560 BOGIE CRS
11938 OVER HEADSTOCKS
12778 OVER PULLING LINES
8560 INSIDE HOPPER
676
2438 OVER BOLSTER
2743 MAX WIDTH
2134 HOPPER OPEN
3680 (TARE)
SHUNTERS STEP
1435 GAUGE
BODY ARRGT — DRG. Nº 54595
BOGIES 1435 — DRG. Nº B.K. 10365 %s
JOURNAL SIZE — 280 X 140
WEIGHT ON RAIL — 76 t
TARE — 15·550 t
LOAD — 60·450 t
AIR BRAKE — WESTINGHOUSE (WF2)
BRAKE CYLINDER — φ 203 X 203
BRAKE % AIR (EQUIV. CAST IRON) — TARE 78·75 % — LOAD 40·29 %
BRAKE % HAND (EQUIV CAST IRON) — TARE 99·87 % — LOAD 20·43 %
EMPTY LOAD BRAKE — YES
GRADE CONTROL — NO.
CHIEF MECHANICAL ENGINEER
DIAG. Nº 12/51300
W.A.G.R.
CLASS WL
SALT HOPPER WAGON
DRN.
T.C.D.
CKD.
P.D.E.


J - 12
COMPARTMENT CAPACITIES:- PETROL - 7,829 GALLONS
DISTILLATE - 7,000 "
* A.T.K. - 7,531 "
COMPARTMENT CAPACITIES:- PETROL - 5280 GALLONS
DISTILLATE - 4720 "
* A.T.K. - 5,079 "
VACUUM RELIEF VALVE
SIDE DISCHARGE PIPES
INBOARD JACKING PAD
HIGHLY INFLAMMABLE
EMPTY/LOAD CHANGE OVER
RELEASE WIRE
EMPTY/FULL INDICATOR
℄ COUPLER
"MINER" TYPE HANDBRAKE
SHUNTER'S STEP
(12'-6") OVERALL TARE HEIGHT 3810
CAST STEEL RIDE CONTROL BOGIE (WABCOPAC BRAKE) ROLLER BEARINGS, WHEELS (3'-1") DIA. 940
16 154 (53'-0") BOGIE CENTRES
20 168 (66'-2") OVER END SILLS
21 031 (69'-0") OVER PULLING LINES
RAIL LEVEL
DISCHARGE VALVE
OPERATING HANDLE
DIPSTICK GUIDE
MANHOLE
FILLING PIPE
(5") SAFETY 127 VALVE
(8'-0") INSIDE DIA 2 438
(9'-3") INSIDE DIA 2 819
(64'-8") OVER TANK ENDS 19 710
NOTE: METRIC EQUIVALENTS SHOWN TO NEAREST MILLIMETRE AND KILOGRAM
* A.T.K. - AVIATION TURBINE KEROSENE
BODY ARRGT. | DRG. No. 52997
BOGIES 4'-8½" GAUGE | DRG. No. 52490 AAR 2D
JOURNAL SIZE | 11" X 6" EQUIVALENT
WEIGHT ON RAIL | (93T - 15C - 0Q) 95 254 kg
TARE | (22T - 14C - 1Q) 23 077 kg
LOAD | (71T - 0C - 3Q) 72 177 kg
AIR BRAKE | WESTINGHOUSE (ABSD)
BRAKE CYLINDER | 4 X 9" DIA. ON BOGIES
BRAKE % AIR (EQUIVALENT CAST IRON) | TARE 49.2% | LOAD 29.8%
BRAKE % HAND (EQUIVALENT CAST IRON) | TARE 36.3% | LOAD 8.7%
EMPTY/LOAD BRAKE | YES
GRADE CONTROL | No
CAPACITY PET. .73 SG | 20,938 GALS.
CAPACITY DIST. .85 SG | 18,720 GALS.
CAPACITY A.T.K. .79 SG | 20,141 GALS.
CHIEF MECHANICAL ENGINEER
DIAG. No. 10K/51300
W.A.G.R.
CLASS | WJK
TANK (3 COMPARTMENT) PETROL - DISTILLATE - A.T.K. - BP.
DRN. E.M. 13-11-70
TCD. S.W. 18.11.70
CKD.
PDE.


J - 13
4 SAFETY VALVES (5" DIA) 127
2 FILL PIPES
2 RELIEF VALVES
MANWAY (1'-8" DIA) 508
INBOARD JACKING PAD
TWO 4" DIA DISCHARGE VALVES
CAST STEEL RIDE CONTROL BOGIES (WABCOPAC BRAKE) ROLLER BEARINGS, WHEEL (3'-1" DIA) 940
RAIL LEVEL
ELLCON HANDBRAKE
EMPTY/FULL INDICATOR
A.B.S.D. VALVE
MANUAL EMPTY/LOAD CHANGEOVER DEVICE
℄ COUPLER
(10'-6") OVER LADDERS 3200.4
(12'-6") OVERALL TARE HEIGHT 3810
15291 (50'-2") BOGIE CENTRES
18409 (60'-4¾") OVER HEADSTOCKS
19426 (63'-8 13/16") OVER PULLING LINES
17424 (57'-2") OVER TANK ENDS
DISCHARGE VALVE OPERATING HANDLES
(9'-1") INSIDE DIA 2769
(8'-0") INSIDE DIA 2438
(9'-2") OVER HEADSTOCK CHANNELS 2794
AUTO-INTER LOCKING COUPLER TYPE F
BODY ARRG'T | DRG. No. 53884
BOGIES 4'-8½" GAUGE | DRG. No. 52830
JOURNAL SIZE (279 X 152) | 11" X 6" EQUIVALENT
WEIGHT ON RAIL | (93T-15C-0Q) 95254 kg
TARE | (20T-0C-0Q) 20321 kg
LOAD | (73T-15C-0Q) 74933 kg
AIR BRAKE | WESTINGHOUSE (ABSD)
BRAKE CYLINDER (229) | 4 X 9" DIA ON BOGIES
BRAKE % AIR (EQUIV. CAST IRON) | TARE 45.4% | LOAD 24.2%
BRAKE % HAND | TARE 97.7% | LOAD 20.8%
EMPTY / LOAD BRAKE | YES
GRADE CONTROL | NO
CAPACITY FUEL OIL .93 SG | 17,763 gals.
CAPACITY DIST. .85 SG | 19,435 gals.
CHIEF MECHANICAL ENGINEER
DIAG. No 11L/51300
W.A.G.R.
CLASS | WJL
TANK SHELL FUEL OIL - DISTILLATE


J-5
FILL CAP
(6'-4")CRS.
1930
MANHOLE
FILL CAP
HAND BRAKE
EMPTY/ FULL INDICATOR
HIGHLY INFLAMMABLE
INBOARD JACKING PAD
SIDE DISCHARGE PIPES
RAIL LEVEL
℄ WAGON
EMPTY/LOAD CHANGE OVER
RELEASE WIRE
℄ COUPLER
889 (2'-11") TARE HT.
SHUNTER'S STEP
CAST STEEL RIDE CONTROL BOGIES (WABCOPAC BRAKE) ROLLER BEARINGS, WHEELS (3'-1")DIA. 940
(5'-9") CRS. 1753
(6'-0¾") 1848
15 557 (51'-0⅝") BOGIE CENTRES
19 253 (63'-2") OVER END SILLS
20 117 (66'-0) OVER PULLING LINES
(7'-9")OUTSIDE DIA. 2 362
(9'-0")OUTSIDE DIA. 2 743
DIP STICK GUIDE
(5")SAFETY VALVE 127
(9'-0")OVER ENDSILL 2 743
(59'-0¼")OVER TANK ENDS 17 996
"MINER" TYPE HANDBRAKE
(13'-9¼")OVERALL TARE HEIGHT 4 197
BODY ARRGT. TULLOCH LTD.DRG.No.21553
BOGIES 4'-8½" GAUGE DRG. No. 50466 AAR 2D
JOURNAL SIZE 11"X6" EQUIVALENT
WEIGHT ON RAIL (93T - 15C - 0Q) 95 254 kg
TARE (19T - 13C - 0Q) 19 965 kg
LOAD (74T - 2C - 0Q) 75 289 kg
AIR BRAKE WESTINGHOUSE (ABSD)
BRAKE CYLINDER 4 X 9" DIA. ON BOGIES
BRAKE % AIR (EQUIVALENT CAST IRON) TARE 56·8% LOAD 29·8%
BRAKE % HAND (EQUIVALENT CAST IRON) TARE 41·9% LOAD 8·7%
EMPTY/ LOAD BRAKE YES
GRADE CONTROL No
CAPACITY PET. ·73 SG 20,103 GALS.
CAPACITY DIST. ·85 SG 19,522 GALS.
NOTE: METRIC EQUIVALENTS SHOWN TO NEAREST MILLIMETRE AND KILOGRAM.
CHIEF MECHANICAL ENGINEER
DIAG. No. 10D/51300
W.A.G.R.
CLASS WJD
TANK
PETROL-DISTILLATE-MOBIL
DRN. E.M. 17-8-70
TCD. S.W. 20.8.70
CKD.
PDE.

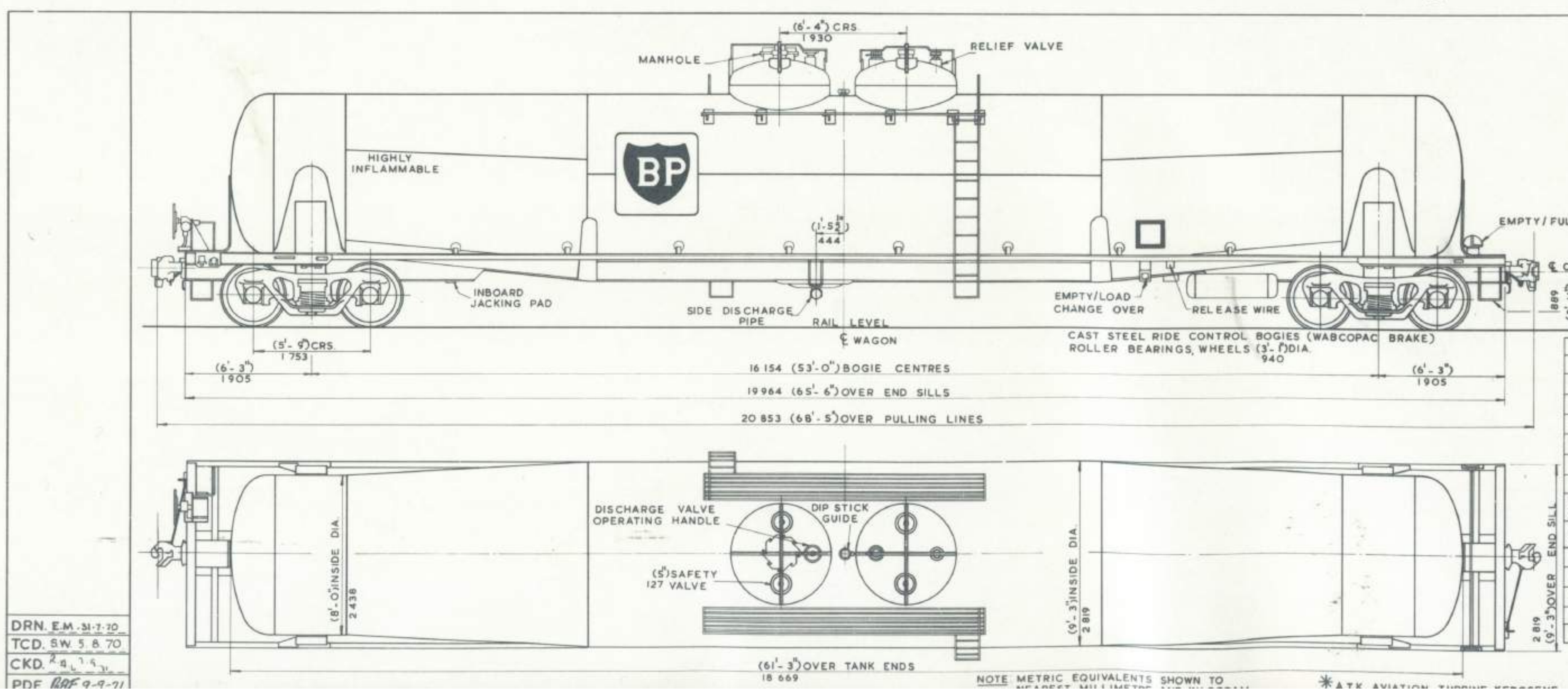

J-6
(6'-4") 1930
EMPTY/FULL INDICATOR
HIGHLY INFLAMMABLE
INBOARD JACKING PAD
SIDE DISCHARGE PIPE
RAIL LEVEL
℄ WAGON
EMPTY/LOAD CHANGE OVER
RELEASE WIRE
℄ COUPLER
889 (2'-11") TARE HT.
SHUNTER'S STEP
CAST STEEL RIDE CONTROL BOGIES (WABCOPAC BRAKE) ROLLER BEARINGS, WHEELS (3'-1")DIA. 940
(5'-9")CRS. 1753
(6'-0¾") 1848
17 234 (56'-6½") BOGIE CENTRES
20 930 (68'-8") OVER END SILLS
21 793 (71'-6") OVER PULLING LINES
(7'-9")OUTSIDE DIA. 2 362
(9'-0")OUTSIDE DIA. 2 743
DISCHARGE VALVE OPERATING HANDLE
DIP STICK GUIDE
127 (5")SAFETY VALVE
(9'-0")OVER END SILL 2 743
(64'-6½")OVER TANK ENDS 19 672
"MINER" TYPE HANDBRAKE
(13'-9¼")OVERALL TARE HEIGHT 4 197
BODY ARRGT. TULLOCK DRG.No. 21552
BOGIES 4'-8½" GAUGE DRG.No.50466 AAR 2D
JOURNAL SIZE 11"X6" EQUIVALENT
WEIGHT ON RAIL (93T-15C-0Q) 95 254 kg
TARE (19T-17C-1Q) 20 181 kg
LOAD (73T-17C-3Q) 75 073 kg
AIR BRAKE WESTINGHOUSE (ABSD)
BRAKE CYLINDER 4 X 9" DIA. ON BOGIES
BRAKE % AIR (EQUIVALENT CAST IRON) TARE 56·2% LOAD 29·8%
BRAKE % HAND (EQUIVALENT CAST IRON) TARE 41·5% LOAD 8·7%
EMPTY/LOAD BRAKE YES
GRADE CONTROL No
CAPACITY PET. ·73 SG 21,777 GAL.
CAPACITY DIS. ·85 SG 19,472 GAL.
NOTE: METRIC EQUIVALENTS SHOWN TO NEAREST MILLIMETRE AND KILOGRAM
CHIEF MECHANICAL ENGINEER
DIAG. No. 11E/51300
W.A.G.R.
CLASS WJE
TANK
PETROL-DISTILLATE-MOBIL
DRN. E.M. 6-11-70
TCD. S.W. 9-11-70
CKD.



BODY ARRG'T.	DRG. No. 52978	
BOGIES 4'-8½" GAUGE	DRG. No. 52490 AAR 2D	
JOURNAL SIZE	11"x6" EQUIVALENT	
WEIGHT ON RAIL	(93T - 15C - 0Q) 95 254 kg	
TARE	(20T - 7C - 0Q) 20 676 kg	
LOAD	(73T - 8C - 0Q) 74 578 kg	
AIR BRAKE	WESTINGHOUSE (ABSD)	
BRAKE CYLINDER	4 X 9" DIA. ON BOGIES	
BRAKE % AIR (EQUIVALENT CAST IRON)	TARE 54·8 %	LOAD 29·8 %
BRAKE % HAND (EQUIVALENT CAST IRON)	TARE 40·5 %	LOAD 8·7 %
EMPTY/LOAD BRAKE	YES	
GRADE CONTROL	No	
CAPACITY PET ·73 SG	21,626 GALS.	
CAPACITY DIST ·85 SG	19,336 GALS.	

DIAG. No. 10F/51300

W.A.G.R.	
CLASS	WJF
TANK-MOBIL PETROL-DISTILLATE	

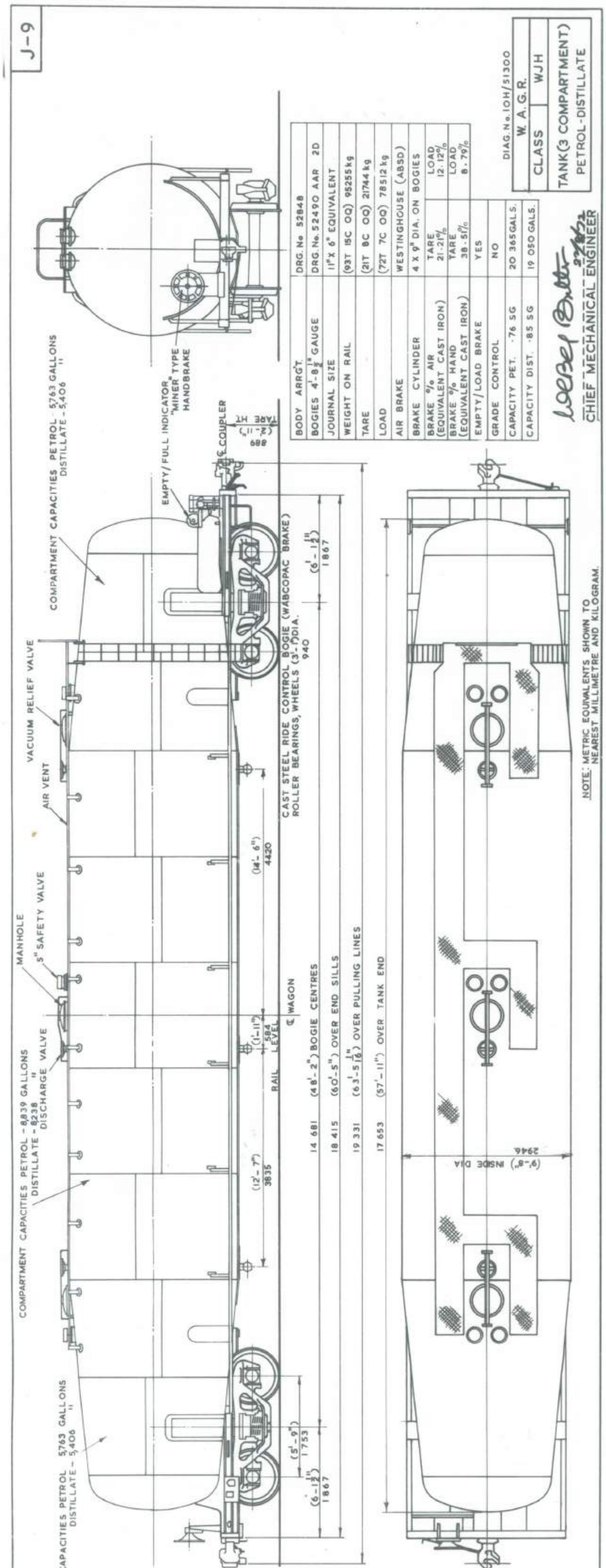


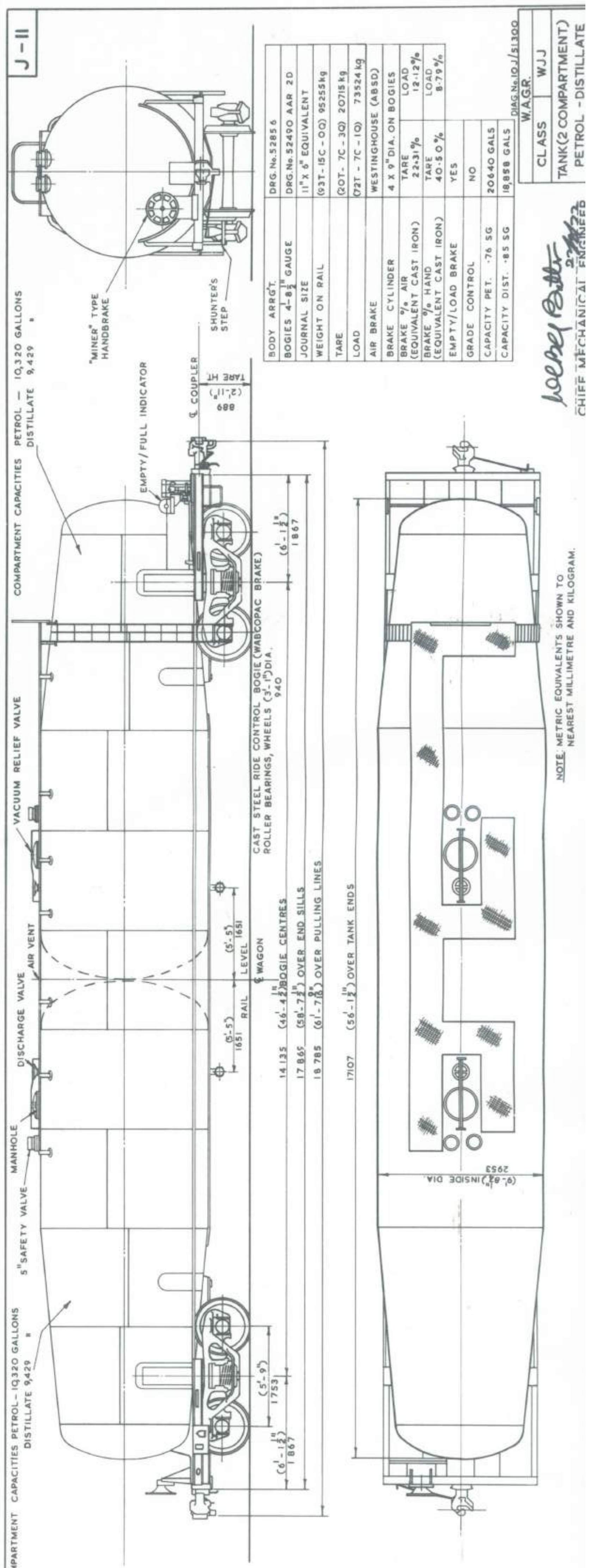
BODY ARRG'T.	DRG. No. 52985	
BOGIES 4'-8½" GAUGE	DRG. No. 52490 AAR 2D	
JOURNAL SIZE	11"x6" EQUIVALENT	
WEIGHT ON RAIL	(93T - 15C - 0Q) 95 254 kg	
TARE	(20T - 2C - 0Q) 20 422 kg	
LOAD	(73T - 13C - 0Q) 74 832 kg	
AIR BRAKE	WESTINGHOUSE (ABSD)	
BRAKE CYLINDER	4 X 9" DIA. ON BOGIES	
BRAKE % AIR (EQUIVALENT CAST IRON)	TARE 55·5 %	LOAD 29·8 %
BRAKE % HAND (EQUIVALENT CAST IRON)	TARE 41·0 %	LOAD 8·7 %
EMPTY/LOAD BRAKE	YES	
GRADE CONTROL	No	
CAPACITY PET. ·73 SG.	21,700 GALS.	
CAPACITY DIST. ·85 SG.	19,405 GALS.	
CAPACITY A.T.K. ·79 SG.	20,880 GALS.	

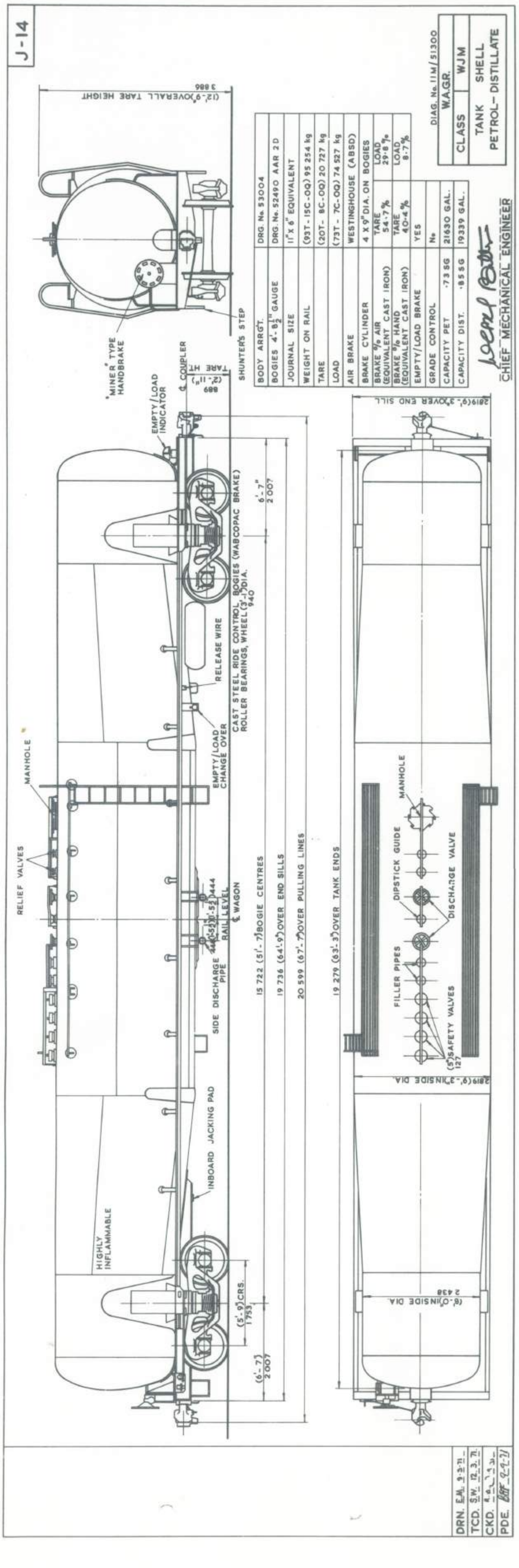
DIAG. No. 10G/51300

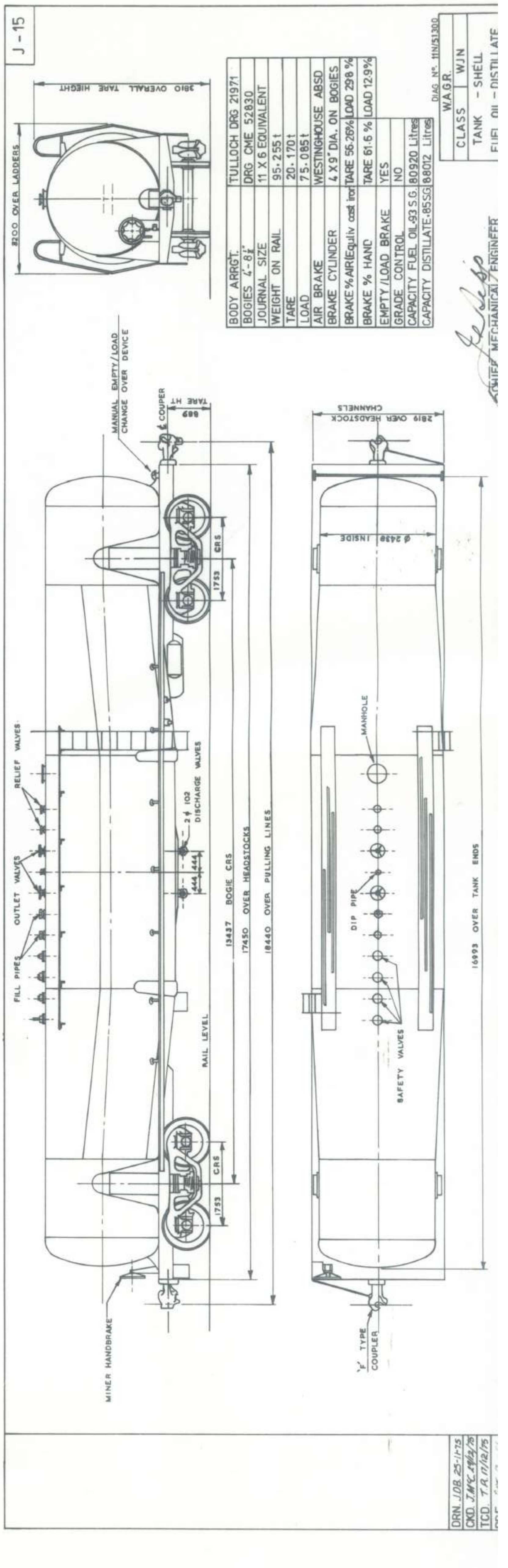
W.A.G.R.	
CLASS	WJG
TANK - B.P. A.T.K.-PETROL-DISTILLATE	

* A.T.K. AVIATION ...


J-9
COMPARTMENT CAPACITIES PETROL 5,763 GALLONS
DISTILLATE - 5,406 "
COMPARTMENT CAPACITIES PETROL - 8,839 GALLONS
DISTILLATE - 8,238 "
DISCHARGE VALVE
MANHOLE
5" SAFETY VALVE
AIR VENT
VACUUM RELIEF VALVE
EMPTY/FULL INDICATOR
"MINER" TYPE HANDBRAKE
℄ COUPLER
TARE HT
℄ WAGON
RAIL LEVEL
CAST STEEL RIDE CONTROL BOGIE (WABCOPAC BRAKE)
ROLLER BEARINGS, WHEELS (3'-1")DIA. 940
14 681 (48'-2") BOGIE CENTRES
18 415 (60'-5") OVER END SILLS
19 331 (63'-5 1/8") OVER PULLING LINES
17 653 (57'-11") OVER TANK END
(9'-8") INSIDE DIA 2946
NOTE: METRIC EQUIVALENTS SHOWN TO NEAREST MILLIMETRE AND KILOGRAM.
BODY ARRG'T. | DRG. No 52848
BOGIES 4'-8 1/2" GAUGE | DRG. No. 52490 AAR 2D
JOURNAL SIZE | 11" X 6" EQUIVALENT
WEIGHT ON RAIL | (93T 15C OQ) 95255 kg
TARE | (21T 8C OQ) 21744 kg
LOAD | (72T 7C OQ) 78512 kg
AIR BRAKE | WESTINGHOUSE (ABSD)
BRAKE CYLINDER | 4 X 9" DIA. ON BOGIES
BRAKE % AIR (EQUIVALENT CAST IRON) | TARE 21·21% | LOAD 12·12%
BRAKE % HAND (EQUIVALENT CAST IRON) | TARE 38·51% | LOAD 8·79%
EMPTY/LOAD BRAKE | YES
GRADE CONTROL | NO
CAPACITY PET. ·76 SG | 20 365 GALS.
CAPACITY DIST. ·85 SG | 19 050 GALS.
CHIEF MECHANICAL ENGINEER
DIAG. No. 10H/51300
W. A. G. R.
CLASS | WJH
TANK (3 COMPARTMENT) PETROL-DISTILLATE
DRN. E.M. 28-1-72
TCD. S.W. 1.2.72


J-11
COMPARTMENT CAPACITIES PETROL - 10,320 GALLONS
DISTILLATE 9,429 "
5" SAFETY VALVE
MANHOLE
DISCHARGE VALVE
AIR VENT
VACUUM RELIEF VALVE
EMPTY/FULL INDICATOR
"MINER" TYPE HANDBRAKE
SHUNTER'S STEP
℄ COUPLER
TARE HT
℄ WAGON
RAIL LEVEL
CAST STEEL RIDE CONTROL BOGIE (WABCOPAC BRAKE)
ROLLER BEARINGS, WHEELS (3'-1")DIA. 940
14 135 (46'-4 1/2") BOGIE CENTRES
17 865 (58'-7 3/8") OVER END SILLS
18 785 (61'-7 5/8") OVER PULLING LINES
17107 (56'-1 1/2") OVER TANK ENDS
(9'-8 1/4") INSIDE DIA 2953
NOTE METRIC EQUIVALENTS SHOWN TO NEAREST MILLIMETRE AND KILOGRAM.
BODY ARRG'T. | DRG. No. 52856
BOGIES 4'-8 1/2" GAUGE | DRG. No. 52490 AAR 2D
JOURNAL SIZE | 11" X 6" EQUIVALENT
WEIGHT ON RAIL | (93T-15C-OQ) 95255 kg
TARE | (20T-7C-3Q) 20715 kg
LOAD | (72T-7C-1Q) 73524 kg
AIR BRAKE | WESTINGHOUSE (ABSD)
BRAKE CYLINDER | 4 X 9" DIA. ON BOGIES
BRAKE % AIR (EQUIVALENT CAST IRON) | TARE 22·31% | LOAD 12·12%
BRAKE % HAND (EQUIVALENT CAST IRON) | TARE 40·50% | LOAD 8·79%
EMPTY/LOAD BRAKE | YES
GRADE CONTROL | NO
CAPACITY PET. ·76 SG | 20640 GALS
CAPACITY DIST. ·85 SG | 18,858 GALS
CHIEF MECHANICAL ENGINEER
DIAG. No. 10J/51300
W.A.G.R.
CLASS | WJJ
TANK (2 COMPARTMENT) PETROL - DISTILLATE
DRN. E.M. 3-2-72
TCD. S.W. 8.2.72


J-14
BODY ARRGT. DRG. No. 53004
BOGIES 4'-8½" GAUGE DRG. No. 52490 AAR 2D
JOURNAL SIZE 11"X 6" EQUIVALENT
WEIGHT ON RAIL (93T-15C-0Q) 95 254 kg
TARE (20T-8C-0Q) 20 727 kg
LOAD (73T-7C-0Q) 74 527 kg
AIR BRAKE WESTINGHOUSE (ABSD)
BRAKE CYLINDER 4 X 9" DIA. ON BOGIES
BRAKE % AIR (EQUIVALENT CAST IRON) TARE 54.7% LOAD 29.8%
BRAKE % HAND (EQUIVALENT CAST IRON) TARE 40.4% LOAD 8.7%
EMPTY/LOAD BRAKE YES
GRADE CONTROL No
CAPACITY PET. .73 SG 21630 GAL.
CAPACITY DIST. .85 SG 19339 GAL.
CHIEF MECHANICAL ENGINEER
DIAG. No. 11M/51300
W.A.G.R.
CLASS WJM
TANK SHELL PETROL-DISTILLATE
RELIEF VALVES
MANHOLE
EMPTY/LOAD INDICATOR
"MINER" TYPE HANDBRAKE
SHUNTER'S STEP
RELEASE WIRE
EMPTY/LOAD CHANGE OVER
CAST STEEL RIDE CONTROL BOGIES (WABCOPAC BRAKE) ROLLER BEARINGS, WHEEL (3'-1") DIA. 940
SIDE DISCHARGE PIPE
INBOARD JACKING PAD
HIGHLY INFLAMMABLE
RAIL LEVEL
℄ WAGON
15 722 (51'-7") BOGIE CENTRES
19 736 (64'-9") OVER END SILLS
20 599 (67'-7") OVER PULLING LINES
19 279 (63'-3") OVER TANK ENDS
FILLER PIPES
DIPSTICK GUIDE
DISCHARGE VALVE
SAFETY VALVES
3 886 (12'-9") OVERALL TARE HEIGHT
2819 (9'-3") OVER END SILL
2 438 (8'-0") INSIDE DIA
DRN. E.M. [illegible]
TCD. S.W. [illegible]
CKD. [illegible]
PDE. [illegible]


J-15
BODY ARRGT. TULLOCH DRG 21971
BOGIES 4'-8½" DRG CME 52830
JOURNAL SIZE 11 X 6 EQUIVALENT
WEIGHT ON RAIL 95.255t
TARE 20.170t
LOAD 75.085t
AIR BRAKE WESTINGHOUSE ABSD
BRAKE CYLINDER 4 X 9" DIA. ON BOGIES
BRAKE % AIR (Equiv cast iron) TARE 56.26% LOAD 29.8%
BRAKE % HAND TARE 61.6% LOAD 12.9%
EMPTY/LOAD BRAKE YES
GRADE CONTROL NO
CAPACITY FUEL OIL .93 S.G. 80920 Litres
CAPACITY DISTILLATE .85 SG 88012 Litres
CHIEF MECHANICAL ENGINEER
DIAG. Nº. 11N/51300
W.A.G.R.
CLASS WJN
TANK - SHELL FUEL OIL - DISTILLATE
3810 OVERALL TARE HEIGHT
2200 OVER LADDERS
MANUAL EMPTY/LOAD CHANGE OVER DEVICE
℄ COUPLER
RELIEF VALVES
OUTLET VALVES
FILL PIPES
DISCHARGE VALVES
13437 BOGIE CRS
17450 OVER HEADSTOCKS
18440 OVER PULLING LINES
RAIL LEVEL
MINER HANDBRAKE
'F' TYPE COUPLER
MANHOLE
DIP PIPE
SAFETY VALVES
16993 OVER TANK ENDS
2819 OVER HEADSTOCK
CHANNELS
ø 2438 INSIDE
1753 CRS
DRN. J.O.B. [illegible]
CKD. [illegible]
TCD. [illegible]